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# A RAND NOTE



Main Theater Warfare Modeling in the RAND Strategy Assessment System (3.0)

Bruce W. Bennett, Carl M. Jones,
Arthur M. Bullock, Paul K. Davis

September 1988





40 Years 1948-1988
RAND

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Prepared for
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The RAND Strategy Assessment Center

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# PREFACE

This Note provides an *overview* of a theater-level combat model developed for the RAND Strategy Assessment System (RSAS). RSAS development is sponsored by the Director of Net Assessment in the Office of the Secretary of Defense, under the auspices of RAND's National Defense Research Institute, a Federally Funded Research and Development Center sponsored by the Office of the Secretary of Defense. This Note is the first step toward documentation and represents an *interim* attempt to provide information while the model is still evolving. It should be of benefit to current and prospective RSAS users, as well as those interested in modeling theater warfare.

By and large, the RSAS is emphasizing on-line documentation rather than detailed publications that quickly become obsolete. In addition, the RSAS is stressing user-friendly data structures that allow users to understand much of the model's content directly from those structures. Nonetheless, some written documentation is essential, and that being developed includes: this overview, a description of the various parameters used in the theater model, and a reference manual. Comments are especially welcome since the authors will be improving the model for some time.

# SUMMARY

This Note provides an overview of the main theater warfare model developed for the RAND Strategy Assessment System (RSAS) in its effort to define new analytic methods based on the structure of global political-military war gaming.[1] This model covers land and air combat in Central Europe and Korea; a separately documented model covers other theaters.[2] These models are part of a global combat model (CAMPAIGN) providing a fully integrated treatment of conventional, theater-nuclear, and intercontinental-nuclear warfare worldwide. CAMPAIGN, in turn, is part of a larger system that includes national-level political models concerned with issues such as grand strategy, escalation, and termination.[3] The RSAS emphasizes a strategic-level view of events relevant to national leaders or theater commanders rather than, for example, corps commanders.

## MODEL PHILOSOPHY

There is constant tension between the desire to enrich simulations and the desire to exclude unnecessary details to maintain a *comprehensible* strategic-level (theater-level and up) view. There are also tradeoffs between enrichment and simulation speed. The tension endures because some "lower-level details" can have strategic-level consequences and because theater warfare is a stochastic phenomenon that

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[1]The RSAS effort is outlined in Paul K. Davis and James A. Winnefeld, *The RAND Strategy Assessment Center: An Overview and Interim Conclusions About Utility and Development Options*, The RAND Corporation, R-2945-DNA, March 1983.

[2]The secondary theater model currently covers Northern Europe, Southern Europe, Southwest Asia, and Cuba. It is described in Patrick D. Allen and Barry A. Wilson, *Secondary Land Theater Model*, The RAND Corporation, N-2625-NA, July 1987.

[3]See, for example, Paul K. Davis and William L. Schwabe, *Search for a Red Agent*, The RAND Corporation, P-7107, July 1985; and Paul K. Davis and Peter J. E. Stan, *Concepts and Models of Escalation*, The RAND Corporation, R-3235, May 1984.

is not well-represented by examining only average events or best-estimate assumptions. By and large, the RSAS work emphasizes breadth over depth. We also stress the value of a single analyst being able to operate and comprehend the simulation in terms familiar to theater commanders rather than to computer programmers. Consistent with this, we place a high premium on making it easy to ask "What if?" questions from a strategic perspective and to get answers back in minutes rather than hours. All of this implies a high level of aggregation but it does not mean that we can ignore issues such as maneuver. To the contrary, we have taken pains to include a broad range of maneuver effects in our model but to do so in ways consistent with our strategic-level perspective and high levels of aggregation. We have also provided the analyst tools with which to test the sensitivity of results to non-best-estimate assumptions, in large part because the results of maneuver warfare are very sensitive to the details of the scenario. Finally, we have taken the view that the model described here should not be regarded as something to be used in isolation but rather something to be used in combination with higher-resolution maneuver games (e.g., IDAHEX or the emerging JTLS), which provide insights that can then be reflected in the way one uses our more aggregated model.

## MODEL CHARACTER

All of the RSAS models are designed to be used either as closed simulations or as interactive games. Thus, an analyst may conduct a dozen runs varying a few parameters carefully, a human team may play against an automated opponent (e.g., a Blue team versus a "Red Agent"), or Red and Blue teams may play each other. To accomplish this diversity, we have drawn on results of human play by knowledgeable officers to provide a set of optional rule-based, command-control decision models akin to "expert systems." These can be used to make daily decisions about the allocation of reserves, apportionment of air forces, adjustment of corps boundaries, and so on. We also provide a set of standardized order sets that reduce the burden on human teams.

Consistent with more general principles, the Red and Blue decision models and order sets are quite different from one another and are becoming increasingly so over time.[4]

## MODEL CONTENT

The model follows Red divisions and Blue brigades along axes of advance, running across a roughly rectangular grid. The geographic resolution is low, with sectors generally in the range of 40-100 km on a side. The decision processes of division commanders (and, in some instances, corps commanders) are relatively submerged because the model's focus is on echelons above corps and particularly on the theater commander's perspective.

At the same time, the model includes far *more* detail than has been customary in many other models. For example, it tracks such unit characteristics as nationality, cohesiveness, composition, and level of training. It also allows the user to vary assumptions about a broad range of qualitative and quantitative issues such as national fighting effectiveness, maximum combat intensity, the intensity of sustainable combat, exchange ratios from prepared defenses, effectiveness of close air support and helicopters in imposing attrition and delay, defender strategy, and attacker strategy.

The model is also unique in its treatment (at an aggregated level) of maneuver. It allows the attacker and defender to have explicit concepts of maneuver at corps level and above, with main-thrust axes differentiated from axes for holding actions or follow-on attacks. It allows movement from one corps sector to another (with optional constraints on nationality) and requires both sides to allocate forces for flank protection. An attacker may attempt a strategic-level envelopment (cutting across the rear of one or more opposing corps or armies). It permits the defender to mount counteroffensives.

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[4]See, for example, Bruce W. Bennett, *Reflecting Soviet Thinking in the Structure of Combat Models and Data*, The RAND Corporation, P-7108, April 1985.

Especially important to the treatment of maneuver is the concept of *phases of battle* (preparation, assault, breakthrough, exploitation, and pursuit), without which it is virtually impossible to understand the results of historical battles or even to produce battles in which the overall exchange ratio is not strongly favorable to the defender. The model predicts breakthroughs and large, local one-time losses to the defender under conditions where such breakthroughs regularly occur in higher-resolution human gaming. For example, even if an attacker can achieve only a modest force ratio, the defense can still suffer a breakthrough if it is attempting to cover too large a frontage, because, in the real world, the attacker would be able to conduct tactical-level flanking operations. In a similar vein, it is possible for the attacker to insert an operational maneuver group into the defender's rear under selected conditions. When this occurs, the defender's frontal forces suffer a loss of effectiveness and, in some cases, a breakthrough occurs; this entire process is receiving more attention as a new rear-battle model is being added to CAMPAIGN. Finally, the model allows the user to invoke a breakthrough directly as part of a test of the defense's robustness against highly plausible but not best-estimate events. In this instance, the user decrees where and when the breakthrough occurs and how far the advance will go before it pauses. Whether the breakthroughs are adjudicated by the model or invoked by the analyst as a sensitivity, their ultimate effect depends on whether the defender can supply sufficient operational reserves to contain the breakthrough.

The model also incorporates some initial air-land interactions going beyond the treatment of air power as mere firepower. Close air support, battlefield interdiction, and rotary-wing aircraft can all impose both attrition and delay. Moreover, in sufficient numbers, they can defeat an operational maneuver group during the period of its initial insertion. Although the quantitative relationships assumed are both elementary and highly uncertain (as is the case with many other aspects of theater modeling), they have the effect of changing the way analysts or players think about aircraft. All the parameters, of course, are readily variable.

CAMPAIGN allows for two different representations of the air war: (1) the nominal CAMPAIGN version, and (2) the optional "TacSage" version (a more detailed model developed by our colleagues at RAND). The nominal model reflects the operation of Blue air squadrons and Red air regiments. It handles sortie generation, mission planning, air-to-air combat, interdiction, and supports the air-ground interactions discussed above.

The model includes many logistics effects at a high level of aggregation. Strategic mobility is explicit and deals with combat forces and support packages separately (but not support units). The model tracks days of supplies for ground forces by nationality and permits optional sharing of supplies among allies. Air supplies are followed by type, such as Mavericks or Sidewinders. Movement of supplies is simulated crudely. Many damaged weapon systems are repairable. Each geographic zone is characterized by trafficability and LOC vulnerability, and movement through that zone can be reduced by a level of interdiction reflecting the LOC vulnerability.

## FLEXIBILITY

The CAMPAIGN model overall emphasizes flexibility and the ability to address "What if?" questions quickly. The computer program incorporates modern software techniques that greatly enhance both interactiveness and speed. A user can perform an excursion and receive results within minutes (the simulation runs in about 20 seconds per day of combat on a Sun 3). Not only are nearly all quantitative parameters addressable in the data base, the most frequently used parameters can be changed with direct commands and the commands for doing so are provided with an on-line "help" file that can be kept up to date far more effectively than can hard-copy documentation.

## GRAPHICS AND OTHER OUTPUTS

On-line color graphics greatly facilitate interactive operations during a game or simulation. They also revolutionize post-run analysis of multiple scenarios: Instead of plowing through computer output, the analyst can review results displayed as maps or bar charts at instants in time or as various graphs over time (e.g., FLOT positions, attrition, or rates of advance). Hard-copy color graphics can be produced in about 30 seconds each. More often than not, we use both on-line and hard-copy graphics that show direct comparisons among runs, thus allowing us to see *differences* at a glance. Upon discovering interesting cases, the analyst can examine numerous detailed tabular outputs on a day-to-day basis throughout the simulated war. This is important for verifying the model's behavior and for analysis of complex operations.

## MODEL STATUS

The model is currently operational in its version 3.0, while earlier versions have been used in test applications at RAND.[5] The model is installed in several government agencies. There are a few known deficiencies in the model, but it is possible to work around most of them by judicious use of data. In most of these areas, we are still working to correct specific problems or enhance current representations. In general, it already appears that the model is better (in our view) than comparable alternatives. For example, we are dissatisfied with our air-land interactions, but most theater-level models virtually ignore these except to perhaps assign firepower scores to aircraft. Similarly, we are not yet satisfied with our treatment of several maneuver effects but believe our treatment to be better than existing alternatives for models at the same level of detail.

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[5]Paul K. Davis, *Game Structured Analysis as a Framework for Defense Planning*, The RAND Corporation, P-7051, January 1985.

## ACKNOWLEDGMENTS

The authors are grateful to many people for their help in the development of the theater warfare part of CAMPAIGN. Milton Weiner and Louis Wegner provided the framework for our early ground forces model and have since provided advice and help on many occasions. Lawrence Painter, John Turner, and Patrick Allen have also helped in various phases of implementation. Robert Howe was the first to exercise the early model in a serious study, and he provided numerous suggestions for improvements. Many members of the DOD Working Group overseeing the RSAS effort have provided suggestions, comments, and help. We also appreciate the efforts of Robert Howe and David Ochmanek in reviewing this Note. However, the authors assume responsibility for any shortcomings in this documentation or the model itself.

## CONTENTS

## FIGURES

## TABLES

# I. INTRODUCTION

As part of the RAND Strategy Assessment System's (RSAS) game-structured simulation of global conflict,[1] RAND is developing a model of worldwide conventional and nuclear operations named CAMPAIGN (Combat Assessment Model for Policy Analysis of Issues in Global conflict). This Note provides an overview of the major theater warfare part of CAMPAIGN, which is used for Central Europe and Korea. In addition, there is some discussion of how ground and air forces are represented (for all countries throughout the world), and of related submodels associated with alerting, mobilizing, and deploying forces, and theater nuclear warfare--enough to help the reader understand how CAMPAIGN is actually used.

The RSAS is the product of an ambitious, multiyear project attempting to develop improved tools for strategy analysis. Within this context, the CAMPAIGN model provides an integrated, global perspective, covering conventional and nuclear warfare in multiple theaters, maritime warfare, and strategic nuclear warfare. While designed primarily for analytic purposes, CAMPAIGN is also usable for training and other purposes. The overall RSAS and CAMPAIGN model structures are described in more detail in Sec. II.

The remainder of this Note is organized as follows. Section III describes the way CAMPAIGN represents ground and air forces and their effective combat capability. Section IV describes submodels dealing with mobilization, alerting, and dispersing forces. Section V presents the basic aspects of force movement. Section VI deals with operational- and tactical-level force employment procedures, characterizing the model's treatment of echeloning, allocations, and other aspects of ground force command/control. Section VII then summarizes the submodels

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[1]For discussion of the RSAS efforts more generally, see Paul K. Davis and James A. Winnefeld, *The RAND Strategy Assessment Center: An Overview and Interim Conclusions About Utility and Development Options*, The RAND Corporation, R-2945-DNA, March 1983.

that estimate rates of advance and attrition. Section VIII describes theater air operations. Finally, Section IX discusses the modeling of combat support.

An RSAS prototype became operational in late 1984, while early versions of CAMPAIGN have been used and incrementallv developed since late 1983. This documentation relates to the version of CAMPAIGN contained in RSAS 3.0, released in February 1988. CAMPAIGN will continue to evolve; here we can only describe the current version of CAMPAIGN and some of the changes currently planned.

# II. BACKGROUND

This section begins with a general overview of the RAND Strategy Assessment System to provide a context for the theater model. The CAMPAIGN model is then described in terms of level of detail, submodels (besides the theater combat models), and procedures for use.

## THE RSAS METHODOLOGY

The theater model described herein is a part of the methodology being developed for the RSAS, a multiyear effort that seeks to improve U.S. strategy analysis by combining the best features of political-military war gaming and analytic modeling. The resulting product will be a laboratory for global war gaming of major theater-level conflicts through strategic nuclear warfare. The RSAS is a hybrid combining the strengths of gaming and analytic modeling. War gaming addresses such elements as asymmetries between antagonists, the role of non-superpower countries, the shadow that nuclear forces cast over events below the nuclear threshold, and a wealth of phenomena and operational constraints. In contrast, analytic modeling tends to be more rigorous, reproducible, and faster--facilitating "what if?" sensitivity analyses.

The RSAS approach involves two critical components. First, decision models can be used to replace some or all of the normal human decisionmaking in a war game.[1] These are developed by sampling expert opinion, and then by rigorously playing alternative options in a human "sand-tabling" mode to establish reasonable decision rules for handling situations as they arise. Decision models speed game play, allow the analyst to examine many more scenarios, and impose a rigorous discipline requiring statements of assumptions and rationales. Human teams may

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[1]Readers interested in the relationship of RSAS work to artificial intelligence research (especially "expert systems") should see Paul K. Davis, *RAND's Experience in Applying Artificial Intelligence Techniques to Strategic-Level Military-Political War Gaming*, The RAND Corporation, P-6977, April 1984; and Paul K. Davis and William L. Schwabe, *Search for a Red Agent*, The RAND Corporation, P-7107, July 1985.

still play some or all roles (taking the role of a specific command, for example, in place of the corresponding decision model), or may choose to monitor and selectively override decisions. The human analyst supervising the war game can then control numerous strategy and situational variables as he or she attempts to understand more fully the alternative ways in which a crisis or conflict could develop.

The second critical component is the procedure for analytic modeling embodied in CAMPAIGN. CAMPAIGN (the "Force Agent" within the RSAS structure) evaluates force operations and adjudicates combat in the RSAS. In order to meet the requirements of modeling the full spectrum of conflict in a global context and provide fast run times in an interactive computer environment,[2] a relatively high level of aggregation was selected for forces (e.g., brigades for Blue ground forces and squadrons for Blue air forces), geography (e.g., CONUS is divided into six regions), and targets.[3]

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[2]Fast run time supports two system requirements: sensitivity testing, and the lookahead process. Sensitivity testing involves examining the effects that uncertain variables have on scenario outcome; thus, the faster the model, the more "sensitivities" that can be examined. A "lookahead" is a game-within-a-game in which the player or decision model tests a plan much as military staff would in the real world, but in this case using the entire gaming system to play against the player's perceptions of his opponent. The lookahead tests the feasibility and acceptability of a specific plan, though the results of the lookahead may differ from that of the real game run because of misperceptions of the opponent, incomplete or incorrect information (on weapons systems or other elements of the game), or because the player chooses a model in the lookahead process (e.g., a model of ground combat) that differs from the "real world" model. In any given game, players would likely request a number of lookaheads, and thus CAMPAIGN run time must be fast to allow multiple lookaheads to be completed without excessively slowing the play of the game.

[3]Note that this level of aggregation has required the developers to consider the outcomes of more detailed simulations, exercises, expert opinion, and historical events (where such information is available), and to attempt to tune the RSAS models to appropriately reflect likely outcomes. Users are cautioned that many parameter settings are the results of such tuning exercises; changes to tuning parameters should be made with extreme care and only by someone sufficiently familiar with the models themselves to be able to anticipate the implications and interactions that could occur.

Other major aspects of the analytic modeling include:

- Asymmetries in terminology and operational concepts between Red and Blue are increasingly being reflected.
- Some complicated military phenomena (such as mobile surface-to-air missiles--SAMs--or sabotage of communications nodes) are captured parametrically, without requiring detailed simulation.
- CAMPAIGN facilitates sensitivity testing by allowing the user to "set" most major parameters (e.g., the yield of a nuclear weapon), or to "script" the results of off-line analysis (e.g., the impact of chemical attacks on aircraft sortie rates) into the global warfare simulation.
- Extensive computer graphics support the player and analyst in assessing the implications of various force options and the outcomes of games.

## CAMPAIGN OVERVIEW

Figure 1 provides a simplified view of the CAMPAIGN model and supporting programs. CAMPAIGN is supported by a graphics program (developed by several of our colleagues) and a data base preparation program (Input Processor), which are run separately. These are described in more detail at the end of this section. CAMPAIGN is also supported by online documentation, help facilities, displays, and a series of software "tools" that include a mouse-driven interface and spread sheets for reviewing and changing data.

The heart of CAMPAIGN is a group of theater warfare, naval warfare, strategic warfare, and supporting models. While often developed separately to control complexity, there are significant interactions between them, and in some cases the same submodel is used for multiple purposes (e.g., a single submodel disperses all aircraft types). Also, in some cases users will be able to substitute models at differing levels of detail for the standard RSAS module (e.g., for theater air combat, CAMPAIGN may optionally be run with RAND's more detailed TacSage model replacing the normal air-battle model).

In RSAS 3.0, the main theater model is applied to Central Europe and Korea, while the S/Land model is applied to Northern and Southern Europe, Southwest Asia, and Cuba. Of all the CAMPAIGN elements, the

```
                                                         +--------+
          +--------+     +--------+                   +--| Helps, |
          |Graphics|- - -|CAMPAIGN|      +---------+  |  |Displays|
          |programs|     +--------+      |  User   |  |  +--------+
          +--------+     | Timing |------|Interface|--+
                         +--------+      +---------+  |  +-------+
                             |                        +--|"Tools"|
                             |                           +-------+
                             |
          +-----------+------+-------+------+-----------------+
          |           |              |      |                 |
      +-------+    +-------+         | +----------+     +---------+
      |Theater|    |Naval  |         | |Supporting|     |Strategic|
      |Warfare|    |Combat |         | | Models   |     | Warfare |
      +-------+    +-------+         | +----------+     +---------+
          |           |              |   |                 |
    +-----+-----+     | +----------+ |   | +---------+     | +----------+
    |           |     +-|Operations| |   +-|Strategic|     +-|Operations|
+--------+  +-------+ | +----------+ |   | |  Lift   |     | +----------+
|Theater |  |S/Land | |              |   | +---------+     |
|CAMPAIGN|  |Referee| | +---+        |   |                 | +---+
+--------+  +-------+ +-|ASW|        |   | +---------+     +-|C³I|
  |                   | +---+        |   +-|Targeting|     | +---+
  | +----------+      |              |   | +---------+     |
  +-|Operations|      | +------+     |   |                 | +-----------+
  | +----------+      +-| Land |     |   | +----------+    +-|Engagements|
  |                   | |Attack|     |   +-|  Damage  |      +-----------+
  | +----------+      | +------+     |     |Assessment|
  +-|Air Combat|      |              |     +----------+
  | +----------+      | +-----+      |
  |                   +-|ASuW/|      |
  | +------+          | | AAW |      |
  +-|Ground|          | +-----+    +----+
  | |Combat|          |            |Data|
  | +------+          | +------+   |Base|
  |                   +-|Mining|   +----+
  | +---------+         +------+     |
  +-| Theater |                      |
  | |Commander|                   +---------+
  | +---------+                   |  Input  |
  |                               |Processor|
  | +---------+                   +---------+
  +-|Logistics|
    +---------+
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Fig. 1--A simplified view of CAMPAIGN

main theater model is the most tested because of its relative maturity, whereas the newer naval models are the least tested because they have just been completed.

By design, CAMPAIGN is a deterministic model, though this has caused us to make many difficult tradeoffs when dealing with events that are more nearly random than deterministic (for example, the sinking of a naval vessel or the success or failure of communications over a given path). The decision to use a deterministic or expected value framework results from the concern that a stochastic approach would lead not only to differing outcomes of individual events but, as a result, different decisions by the players that would lead the game down totally different paths. In order to run sufficient cases to establish a frequency distribution of outcomes,[4] the character of the differing paths would largely have to be ignored in favor of a more simplistic comparison of outcomes, which in many cases may not be directly comparable because of the differing circumstances that would be hard to evaluate (given the breadth of global conflict and the potential complexity of the global state). At the same time, we plan in the future to allow for stochastic events in a war-gaming/training context in order to stimulate an appreciation for and responses to unforeseen events. In the meantime, CAMPAIGN allows a game controller to "script" significant events such as breakthroughs or FLOT advances even when such events are not adjudicated by the model (essentially providing a model override), a capability that we find useful not only in gaming applications but also in analysis, given the widely differing points of view on when certain critical events might actually occur.

The vast majority of CAMPAIGN is included in a C language program called Camper, which can be run either as part of the full RSAS or

[4]We are aware of some very large combat models that use what might be referred to as "one-pass Monte Carlo simulation," taking only a single track down a stochastic chain of events. While such model designers usually claim that the large number of events simulated in such models should dampen the variations of outcomes, our experience with the sensitivity testing of such models suggests otherwise, and thus lead us away from such a design concept.

independently. The remaining parts of CAMPAIGN are coded in the Abel language; some of these parts (e.g., naval mining) are designed to run in stand-alone CAMPAIGN (without the full RSAS system), while others (the S/Land Referee and the tactical warning decision tables part of strategic $C^3I$) are available only when the full system is run.

CAMPAIGN itself is a time-driven model with variable time steps. The length of the steps is determined by the world situation and by "wake-up" rules created by human players or the decision models. For example, a Red wake-up rule might be: "If intelligence indications of Blue preparation for a nuclear strike are received, wake me (the human team or automated player) up." Unless a wake-up rule triggers, CAMPAIGN will continue advancing based upon internally determined time steps for whatever duration the analyst has specified. The default time cycles are: 24-hour increments during peacetime, 12-hour increments during mobilization, 4-hour increments during ground and air force deployments and during conventional war, and 1-hour increments or less during strategic nuclear exchanges. The user may also request shorter time cycles.

## GEOGRAPHY IN CAMPAIGN

Geography gives a good perspective on how CAMPAIGN handles detail. To keep CAMPAIGN fast, most forces and targets within the model are located by country. Thus, we would know how many infantry brigades are in Britain, but not where they are within Britain (unless we had arranged to model ground combat there, which we have not). Within ocean areas, some 30 regular sea regions and 20 choke-point regions are identified as areas for locating ships in the same manner. In two instances, CAMPAIGN uses greater geographic detail than individual countries. First, large countries like the United States and the Soviet Union are divided into several regions (for example, the Continental United States is divided into six, the Soviet Union into eight). Second, in areas where theater models are applied (the main theater or S/Land), a much more detailed overlay structure is provided.

Most areas covered by overlays are shown in Fig. 2.[5] Note that theaters are identified by the Red and Blue command for each. For example, the Blue command for Central Europe is referred to as CEur, while the Red command is WTVD (the Western Theater of Military Operations).[6]

In defining the geography of theaters covered by this model, a grid overlay like that shown for Central Europe in Fig. 3 is employed. The grid is developed by dividing the area where major combat is expected

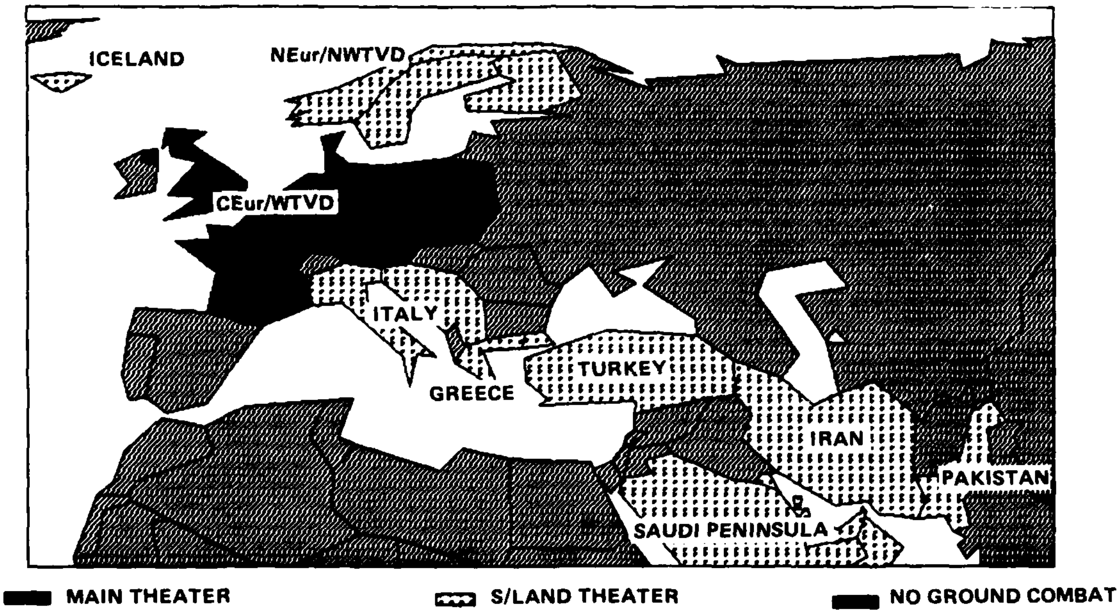


Fig. 2--RSAS combat theaters

[5]Figure 2 does not depict the main theater in Korea, the S/Land theaters in Cuba, or the Baltic Islands.

[6]TVD is the abbreviation of the Russian words which mean theater of military operation. The Western TVD is flanked by the Northwestern TVD (NWTVD) and the Southwestern TVD (SWTVD). In the full RSAS, these commands are often identified as "High Command of Forces"; thus, WTVD is also referred to as High Command of Forces West (HCFW). The S/Land theater is generally referred to as an Army Group (e.g., AG-Italy) or Task Force (e.g., TF-Iceland) for Blue and as a Front (e.g., FR-Turkey) or an Operation (e.g., Op-Cuba) for Red.

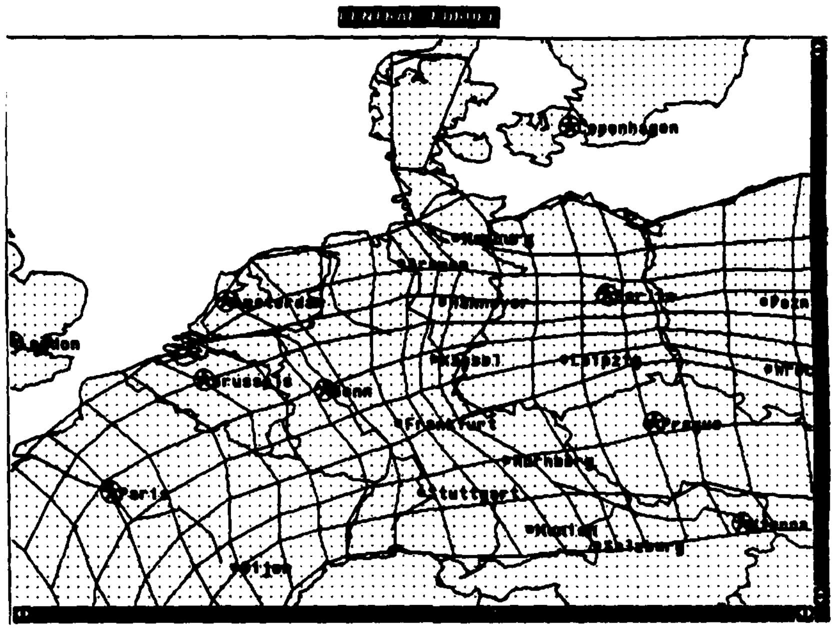

Fig. 3--Geography in the CEur theater

(in this case, in West Germany) into likely avenues of advance (the eight NATO corps sectors, the Landjut sector, and a Danube River axis through Austria). These avenues are extended west and east to cover lines of communication. A set of vertical lines are then overlaid to match river lines and international boundaries as closely as possible, providing a rough grid. Individual cells within the grid are referred to as zones. A given zone might be 80 kilometers wide and 60 kilometers deep. For each zone, we provide data on:

- physical width and combat width
- physical depth and combat depth
- terrain effect on trafficability and defensibility
- LOC capacity (along and across) and vulnerability
- natural or man-made barriers

Combat width and depth refer to the militarily usable part of the geographic width and depth of a zone (where, for example, a mountainous flank would make the combat depth very small, limiting it to passes in the mountains).

Ground-force units are located by zone and by position along the zone's depth. The grid provides a convenient reference system to allow units to move from one location to any other (laterally, longitudinally, or diagonally), recognizing the constraints on movement as the force proceeds. This approach has much in common with that used in older "piston" models of ground combat, but CAMPAIGN includes many processes and interactions going far beyond those of a standard piston approach.

## COMMAND, CONTROL, COMMUNICATIONS, AND INTELLIGENCE

The RSAS is largely a two-sided war game between Blue (the United States) and Red (the Soviet Union). Other countries in the world choose whether to participate in alliances; give overflight, transit, or basing rights; mobilize, alert, or deploy their own forces; and independently execute their strategic nuclear forces (for Britain, France, and China). In the full RSAS, countries other than the United States and the Soviet Union are played by a decision model called the Green Agent;[7] when using stand-alone CAMPAIGN, the analyst enters orders for these countries. Countries modeled by Green still retain some authority over their national forces even when those forces are controlled by Red or Blue as part of an alliance. Thus, while the British Army on the Rhine would be played by Blue as soon as Britain turned control of its forces over to Blue, these forces would still be owned by Britain. This ownership allows specific rules to be established reflecting national preferences (for example, that Danish forces should not be committed to combat in Southern Germany).

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[7]The Green Agent was formerly called the Scenario Agent. See William Schwabe and Lewis M. Jamison, *A Rule-Based Policy-Level Model of Nonsuperpower Behavior in Strategic Conflicts*, The RAND Corporation, R-2962-DNA, December 1982; William Schwabe, *Strategic Analysis as Though Nonsuperpowers Matter*, The RAND Corporation, N-1997-DNA, June 1983; and David A. Shlapak, William L. Schwabe, Mark A. Lorell, and Yoav Ben-Horin, *The RAND Strategy Assessment System's Green Agent Model of Third-Country Behavior in Superpower Crises and Conflict*, The RAND Corporation, N-2363-1-NA, September 1986.

Forces are represented in CAMPAIGN at the brigade-level for Blue ground forces and the division-level for Red ground forces, at the squadron-level for Blue air forces and the regiment-level for Red air forces, and at the vessel/task group-level for naval forces. These forces are assigned to the various global theaters (such as "CEur" or "Intercon" for homeland offense/defense) or to "sub-theaters" reflective of Blue army groups or Red fronts, and then operated by the commands to which they are assigned. Forces assigned to theaters, army groups, or fronts can be deployed to corps sectors and separately controlled in those locations. The RSAS also includes various decision support packages to aid commanders at different levels. For example, the Theater Commander model will shift corps boundaries, move units among corps, or commit reserves based upon general guidance specified by the user.

Currently, the theater model presumes essentially perfect communications for most operations in the theater. An exception is nuclear weapon release, which involves a transmission delay and a probability of correct message receipt.

The theater intelligence model is still in its infancy. As a result, most aspects of intelligence are handled through rough approximations or by controller inputs. For example, the ability to acquire various types of targets in a close air support (CAS) or battlefield air interdiction (BAI) role is a controller input, as is the intelligence factor reflecting a player's knowledge of opposing unit locations when planning battlefield nuclear strikes. In some cases, intelligence is simply handled by providing a time delay on information (e.g., the players usually have dated information with regard to opposing forces), and in other cases intelligence is simply denied (e.g., the strength of opposing units is not available to a player in the war-gaming mode).

## USER INTERFACE

Users may enter commands interactively in response to input prompts, many of which have help options associated with them. CAMPAIGN commands are used to: (1) obtain information through displays (see Table 1 and the examples in Figs. 5 and 6 below), (2) order force actions (see Table 2), (3) set adjudication parameter values, (4) modify operational decision rules, (5) obtain help or explanations, and (6) manipulate various files and records.

The force orders described in Table 2 are used to develop the scenario for each analysis. They are described in more detail in on-line "helps," and in the CAMPAIGN Reference Guide.[8]

All programs run within a "window" environment on a Sun computer. RAND has created a special window for CAMPAIGN that provides many "mouse-driven" procedures for giving CAMPAIGN inputs. Designated the CAMPAIGN Menu Tool (CMenT), this window environment allows the user to perform

Table 1

SOME TYPES OF CAMPAIGN DISPLAYS

| Displays | Graphics |
|---|---|
| Ground combat | Maps of combat theaters |
| Theater air combat | Central Europe |
| Air/ground forces | Korea |
| Naval/missile forces | Political cooperation map |
| Logistics/mobility | Distribution maps |
| Targeting | History graphs (e.g., FLOTs vs. time) |
| Target damage | Strategic targeting bar charts |
| Strategic forces | Location of $C^3I$ facilities |
| Communications | |
| Tactical warning | |

[8]Bruce W. Bennett, Carl M. Jones, Arthur M. Bullock, and Walt L. Perry, *A Reference Guide to the RSAS CAMPAIGN Model*, The RAND Corporation, N-2778-NA.

Table 2

FORCE ORDERS

| Order* | Use |
|---|---|
| Alert | Change the current alert level of specified forces |
| Allocate | Establish corps support shares for theater air |
| Assign | Designate forces to specific theaters |
| Apportion | Detail theater air forces to specific missions |
| Attack | Begin a conventional theater war |
| Control | Commit third country's forces to major alliances |
| Cover | Have AWACS or MPA cover a region |
| Delegate | Commit Air Army aircraft to supporting a specific theater |
| Deny | Refuse overflight, transit, and other rights to allies |
| Deploy | Send a force to a new location |
| Disperse | Direct forces to operate in a dispersed posture |
| Engage | Modify rules of engagement for naval vessels in a region |
| Execute | Implement a preplanned strategic or theater nuclear attack plan |
| Hold | Reduce alert rates of selected air forces |
| Initiate | Begin sabotage or jamming |
| Launch | Order aircraft to assume a state of airborne alert |
| Laydown | Design or change a targeting structure |
| Mission | Establish a mission for a ground force or corps/army |
| Mobilize | Call-up of nonmobilized forces |
| Nest | Establish a new strategic option |
| Permit | Allow overflight, transit, and other rights for allies |
| Plan | Design or change a theater's targeted bombing plan |
| Poise | Send forces to forward attack or defense positions |
| Position | Specify theater geographic objectives for ground forces |
| Retarget | Change the percentage of a force committed to a targeting option |
| Side | Establish alliances for third countries |
| Strike | Implement specific conventional or nuclear strikes |
| Task | Establish mission and rules of engagement for naval groups |
| Terminate | Stop the combat in a specified theater |
| Unassign | Transfer forces from a theater command to strategic reserves |

*In the text, these words will be capitalized when referring to the CAMPAIGN order described here.

most of the functions in the previous paragraph by selecting options from pull-down menus, thus reducing the possibility of incorrect entries.

## OUTPUTS AND GRAPHICS

CAMPAIGN uses a series of computer-generated tabular displays and graphics to capture program outputs, as summarized in Table 1. Many of the individual entries in Table 1 represent more than a single display; for example, the history graphs offer several hundred options for plotting different figures of merit over time. The displays shown in Table 1 are all produced on-line by CAMPAIGN. The graphics are produced by writing a copy of the force data base and reading it into the graphics program (for data at a single point in time) or by writing a history file over time and then reading that file or multiple files (for comparison charts) into the graphics program. Many of the graphics can be windowed or overlaid as well. Figure 4 gives an example of such a history graph, showing the penetration of Soviet forces into the Belgian Corps Sector from D-day through D+10.

A separate "maptool" is used in the full RSAS to display the status of S/Land theaters and of maritime forces. An accompanying "graftool" can display history file information or other time-trends or bar charts.

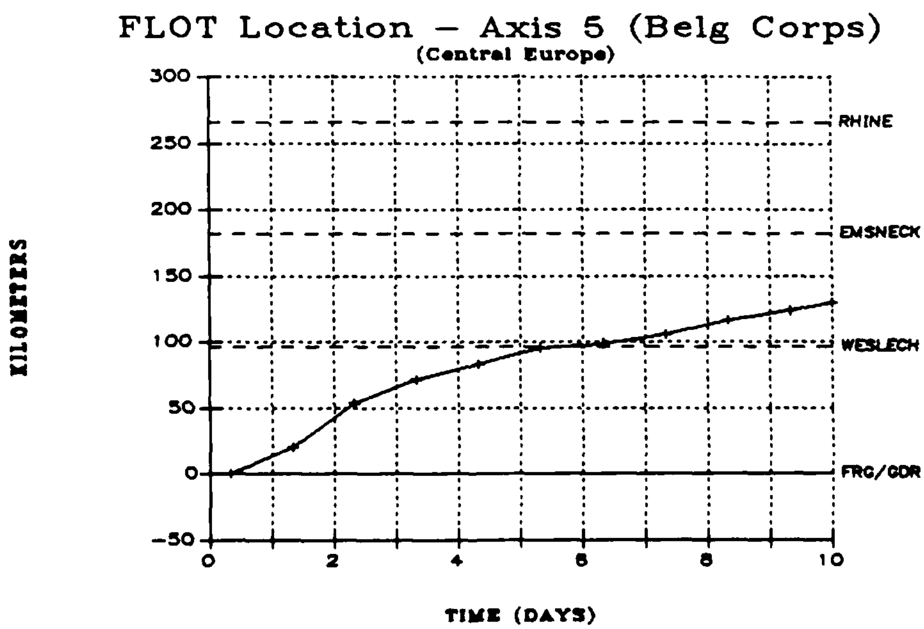


Fig. 4--History graph of Soviet theater operations

Finally, the CMenT interface has a facility mapping capability for global $C^3$ facilities.

## THE INPUT DATA BASE

CAMPAIGN uses a wide variety of data, as summarized in Table 3. The input data files described in Table 3 are located in the Force-C/D directory of the RSAS (a "README" file in that directory describes these files and how to use them). The current version of the CAMPAIGN data base is for approximately mid-1985 and has selected entries for other

Table 3

CAMPAIGN DATA TYPES AND INPUT DATA FILES

| Data Type | Details | Principal data files |
|---|---|---|
| Order of Battle | Air, ground, missile, mobility, naval, space assets<br>Characteristics of these assets<br>Default assignments | air.sec, defense.sec, ground.sec, missile.sec, mobility.sec, navy.sec, space.sec, vessel.sec |
| Weapons | Characteristics<br>Inventories | weapon.sec, weapon2.sec |
| Targets/ Targeting | Facilities<br>Strategic/theater plans<br>Weapon employment rules | comnode.sec, facility.sec, laydown.sec, missile.sec, target.sec, weapon2.sec |
| $C^3I$ | Facilities and characteristics<br>Networks | comlink.sec, comnode.sec, compath.sec, comsys.sec |
| Geography | Regions in the world<br>Paths from region to-region<br>Ground combat overlays | mobility.sec, path.sec, region.sec, theater.sec |
| Parameters | Player controls<br>Force performance<br>Adjudication parameters<br>Modeling options<br>"Scripted" events | nucgov.sec, region.sec, theater.sec |

years (for example, U.S. and NATO combat aircraft are described for 1980 through 1993). In future versions of the RSAS, we hope to provide a capability for the user to select a specific year for analysis and have appropriate forces and other data properly included.

The data base represents the forces of the United States, the Soviet Union, and their allies in a peacetime state. Most forces have default "plans" for assignment to major commands and forward deployment. However, the data is "scenario free" in that any of the defaults can be overridden, and there are no presumptions concerning the duration of preparations for war or of war itself.

In order to make the data most efficient and understandable inside CAMPAIGN, the data are placed into two data structures designed to minimize the requirement for indexed arrays: one contains fixed data and the other contains data that may vary over time. The data structures are currently about 2.7 megabytes in size and contain all of the information necessary for characterizing the current state of the world at a given point in time. The variable data structure can be stored as a single block of data (in about 15 seconds) and later reread by CAMPAIGN (or read by the graphics program) in order to return to a given time or scenario condition.

To put the basic data into the data structure format, a program referred to as the Input Processor is used. It reads data from basic input (flat) files and reformats the data into a computer-efficient (but not readable) data structure format, while at the same time checking the data for inconsistencies or errors. The basic input files are highly readable with many comments and descriptions to explain each data set. Table 4 gives an example of one part of the theater parameter file (from input file theater.sec).

## COMPUTER INFORMATION

The Camper part of CAMPAIGN and associated programs are written in the C programming language. They currently operate on a SUN 3 computer, which uses the Berkeley UNIX 4.2 operating system. The program itself requires about 1.6 megabytes of disk space when stored, and 3.5 MB of

Table 4

A SAMPLE PART OF A BASIC INPUT FILE

```
C________________________________________________________________________
C
C       Section 3D of Theater Table
C________________________________________________________________________
C
C   Note that data in this section may differ between Red and Blue based
C   upon the differences between the standard Red and Blue divisions listed
C   in Section 3C.
C
C
C Data Item    Explanation of Data Item
C
C Thtr         - Name of theater to which the line of data applies
C avg trrn     - The terrain advantage multiplier assumed when specifying the
C                density data here (FULDA is 1.25)
C atk max      - The minimum FLOT across which a standard division (see 3C)
C                can be massed for the attack (attacker shoulder space)
C def max      - The minimum FLOT across which a standard division (see 3C)
C                can be massed for the attack (defender shoulder space)
C Hold         - That FLOT frontage that the standard division can defend
C                with sufficient density and reserves such that an
C                attacker's ability to advance should be reduced by the
C                hold density methodology multiplier
C min          - The maximum FLOT frontage that the standard division can
C                defend while maintaining an adequate operational reserve
C                and not offering any undefended gaps in the defense
C brk          - That FLOT frontage which, if observed by CAMPAIGN, should
C                result in an adjudication of a breakthrough in the axis.  It
C                should represent a low FLOT density and inadequate reserves.
C other wpn    - The fraction of weapons in the infantry categories to be
C                considered in shoulder space calculations.
C tng min      - The fractional training level a force deploying to this
C                theater must attain before commencing deployment (this
C                is an optional entry defaulting to 1.0 if omitted).
C________________________________________________________________________
CThtr          densitv values (kms/std div)
C       avg    ____________________________
C       trrn    atk    def                         other   tng
C               max    max   hold    min    brk     wpn    min
C
 CEur   1.25    10.     15    25      40     60      .2    0.7
 WTVD   1.25     8.     12    20      32     48      .2    0.5
 FEast  1.50     3.      6    12      18     25      .2    0.7
 FETVD  1.50     3.      6    12      18     25      .2    0.7
C
 end of section 3D of Theater Table
```

memory when operating. The graphics program runs about 6 megabytes. A thirty-day war in Central Europe can be simulated and graphics data recorded in about 10 to 15 minutes of time (using stand-alone CAMPAIGN) when the computer is not heavily loaded.

# III. REPRESENTING THEATER FORCES

This section begins by expounding on the design philosophy of the CAMPAIGN model and how it relates to intended model applications. It then describes the level of aggregation chosen for ground and air forces in CAMPAIGN, as well as other factors that describe these forces.

## PHILOSOPHY

In modeling military operations and combat, there is a continual struggle between increasing the detail and complexity versus maintaining comprehension and a reasonable run time for the model. At the center of this struggle is the decision on the level of aggregation at which military forces are represented. Because CAMPAIGN is fundamentally intended as part of an approach to *strategic-level* modeling, it is being developed with a top-down philosophy so that the objects of attention are those of natural interest to national-level or theater-level commanders, but not, for example, corps commanders. Furthermore, because the RSAS approach emphasizes *multiscenario analysis* examining uncertainties in forces, strategies, technical parameters, political contexts, command-control, etc., CAMPAIGN's design places a premium on speed of execution and on flexibility to make changes in assumptions. Frequently, this comes at the expense of detail that might be of considerable interest for other applications.

We have not entirely abandoned issues below the theater-strategic-level, but rather have attempted to include a number of operational art issues to assist in several current and proposed applications. Thus, CAMPAIGN can be used by people interested strictly in a top-down approach where the issues are ones of strategy; alternatively, it can be used in theater-level *sand tabling*, where one explores issues, such as alternative concentrations of force, alternative uses of tactical air, the potential implications of operational maneuver groups, and the potential consequences of early breakthroughs not predicted by best-estimate assumptions. It is not appropriate, however, for study of weapons-level issues, such as the implications of substituting one type of tank for another, nor is it appropriate for doctrinal studies of maneuver.

## RESOLUTION OF GROUND UNITS

CAMPAIGN carries along through the simulation a substantial amount of information about combat units. The resolution is that of NATO brigades or Pact divisions, although the model accommodates other types of units where they play a potentially critical role. Thus, Pact artillery divisions, independent helicopter regiments, and air-assault brigades are represented. Other corps/army subordinated assets such as air-defense units and Pact artillery brigades have their capabilities spread among the appropriate brigades or divisions that they might support.

In describing the characteristics of a real-world unit (e.g., a brigade of the U.S. 24th Mechanized Division), CAMPAIGN would know the unit name, the division (NATO) or army (Pact) to which it belongs, and all of the following at each point in the simulation:

- unit type [e.g., armored (tank), mechanized (motorized rifle), infantry (infantry), and airborne (airborne), for NATO (Pact), respectively]
- location by RSAC region (e.g., US-NE)
- theater to which the unit has been assigned (e.g., CEur)
- type mobility asset with which it is being transported, if applicable (e.g, sealift), as well as the nominal type that would normally transport it (e.g., airborne or POMCUS units normally go by airlift while armored or mechanized units normally go by sealift)
- in a combat theater, location in a "zone" (e.g., 20 kms from the front of Weslek5)
- if committed to a theater, role assigned in that theater (e.g., theater reserve or some echelon in a specific corps or army sector)
- nationality (the "owner" of the capability)

- current status, by category, of its equipment (8 categories: 3 for armor weapons, 2 for infantry weapons, artillery, attack helicopters, and organic air defense)[1]

- an aggregation of equipment strength, measured in equivalent divisions (EDs) as defined below

- readiness (measured in percentage mobilized)

- training status (measured in percentage of full combat effectiveness achieved)

- days of supply for the unit (theater stocks are separately inventoried by owner)

- cohesiveness (in percentages, measured relative to the effectiveness expected from the unit if it were fully trained and fresh with the same equipment)

As this list indicates, CAMPAIGN carries along far more information than is customary in "aggregated models." For example, distinguishing units by nationality proves to be important because NATO is short in operational reserves and the imperfect fungibility of operational reserves across nationalities can be a problem.

With this background, Fig. 5 illustrates a sample of ground force data as would be shown in the ground forces display of CAMPAIGN (this display is generated by typing "display unit army US US-NE"). The first three lines indicate that there is in the Northeastern United States one armored division that happens to be at full strength ("100% PCT") with respect to equipment, but at 60 percent readiness with respect to mobilization of personnel or training. The unit has been assigned to Central Europe and will be deployed there when ready (if a Deploy order has been given). The effective equivalent divisions (EEDs) of the armored division are larger than those for the infantry division, even

[1]Currently, for example, we do not attempt to compute separately attrition for every killer-victim pair. We do handle the actions of attack helicopters and air-defense systems separately, but all other systems are handled by allocating an aggregated attrition estimate among the relevant equipment categories. Even this is useful, and the model has the growth potential to accommodate more disaggregated attrition calculations.

US Ground Forces in US-NE:

| Type Force | Readiness--Status Equip | Mob | EEDs | Assigned Theater | Enroute | Name of Unit |
|---|---|---|---|---|---|---|
| US_armd | 100% | 60% | 0.4 | CEur | CEur | 50TH-ARMD/1ST-BDE [US] |
| US_armd | 100% | 60% | 0.4 | CEur | CEur | 50TH-ARMD/2ND-BDE [US] |
| US_armd | 100% | 60% | 0.4 | CEur | CEur | 50TH-ARMD/3RD-BDE [US] |
| US_inf | 100% | 50% | 0.2 | CEur | CEur | 26TH-INF/1ST-BDE [US] |
| US_inf | 100% | 50% | 0.2 | CEur | CEur | 26TH-INF/2ND-BDE [US] |
| US_inf | 100% | 50% | 0.2 | CEur | CEur | 26TH-INF/3RD-BDE [US] |
| US_inf | 100% | 40% | 0.2 | CEur | CEur | 28TH-INF/1ST-BDE [US] |
| US_inf | 100% | 40% | 0.2 | CEur | CEur | 28TH-INF/2ND-BDE [US] |
| US_inf | 100% | 40% | 0.2 | CEur | CEur | 28TH-INF/3RD-BDE [US] |
| US_inf | 100% | 45% | 0.2 | CEur | CEur | 42TH-INF/1ST-BDE [US] |
| US_inf | 100% | 45% | 0.2 | CEur | CEur | 42TH-INF/2ND-BDE [US] |
| US_inf | 100% | 45% | 0.2 | CEur | CEur | 42TH-INF/3RD-BDE [US] |
| US_mech | 100% | 70% | 0.3 | CEur | CEur | 157TH-MECH [US] |
| US_inf | 100% | 75% | 0.2 | NEur | CEur | 187TH-INF [US] |

Fig. 5--Illustrative ground forces

when both are at 100-percent strength, because armor divisions have more and often better combat equipment.

## MEASURING GROUND UNIT STRENGTH AND EFFECTIVENESS

The strength of ground forces is measured in CAMPAIGN in terms of the equipment held by each unit and personnel/situational factors. This procedure involves two steps: (1) determining the quality and quantity of equipment assigned to a unit, and (2) determining how effectively that equipment would likely be used.

The first step involves aggregating off-line, detailed data on the quality and quantity of unit equipment into the eight categories (three armor, two infantry, artillery, attack helicopters, and air-defense), recording the pieces of equipment and total strength[2] by equipment

[2]Strength is measured using the WEI/WUV III (Weapon Effectiveness Index/Weighted Unit Value) methodology to compare different systems (capturing, for example, the relative capabilities of an M60A3 tank and an M-1 tank). This system is no longer accepted by its originating agency (the Army Concepts Analysis Agency), but we have not found a better alternative. Alternatives may be tested using separate data processing programs available from RAND.

category. The strength values are then aggregated across all categories except attack helicopters and air-defense systems (which are handled via an explicit adjudication in CAMPAIGN) to give an overall unit capability, referred to as "equivalent divisions" (EDs), where 1 ED is defined as the strength level of the 1984 U.S. 1st Armored Division without a slice of corps support assets. Thus EDs measure equipment strength rather than personnel or other factors and are similar to the concept of "armored division equivalents" (ADEs) widely described in the literature.

The second step produces each unit's *effective strength* or Effective Equivalent Divisions (EED) score through multiplying its equipment strength in EDs by a number of effectiveness factors. These factors reflect:[3]

(1) mobilization state

(2) the impact of training on force performance

(3) cohesion problems caused by attrition in combat (which may be offset to some extent by rejuvenation time) or poor training (a modest effect that is in addition to the performance effect in number 2)

(4) a shortfall in supplies

(5) national fighting effectiveness (whether due to military culture, *quality* of training, leadership, or enthusiasm for the cause)

(6) fighting on home territory

(7) language, cultural, and equipment differences of forces of different nationalities operating in the same axis

Currently, these multipliers operate on all classes of equipment equally,[4] although one might argue that there would be greater effects on some capabilities than others. For example, one might wish to give

[3]Tactical surprise and chemical effects also have an effect on the force ratios but are not directly calculated into the unit EED score.

[4]Even the attack helicopter and air-defense effectiveness are enhanced by these factors.

infantry defending in urban sprawl or forests a greater bonus factor than armor. Such fine tuning is possible but not currently implemented.

Because the impact of these factors is uncertain, sensitivity testing their multipliers helps to determine which factors are most important and to what extent they may affect the choices of commanders. For example, how important is the penalty Soviet commanders would pay in force effectiveness by deploying cadred divisions before they were fully trained? Or how much difference does it make if, for example, Polish and Czech forces are not as capable as Soviet units using the same equipment (which the Soviets appear to believe)?[5]

Multipliers must be used with caution, though, because their effects compound. Thus, the baseline for any given analysis might use values of one for the more subjective factors (such as national fighting effectiveness, fighting on home territory, and language and related differences), and modest factors for the others. The analyst should then employ likely alternative values, examining the effect on unit value in some detail (as opposed to simply looking at combat outcomes) when multiple factors are allowed to vary from a value of one. In the end, the analyst must strike a balance between the compounding effects of multipliers, as opposed to understating (or ignoring) the implications of personnel and situational factors that in many historical cases have proven highly significant.[6]

## RESOLUTION OF AIR UNITS

In CAMPAIGN, air forces are usually represented by squadron or regiment, as illustrated in Fig. 6 (a display generated by typing "display unit air US FRG"). Each unit is identified by name (including the wing or division to which it belongs) and is described by other factors such as:

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[5]See, for example, Allan S. Rehm and John F. Sloan, *Operational Level Norms*, Science Applications, Inc., SAI-84-041-FSRC, April 24, 1984, pp. 3.2-3.4.

[6]We applaud T. N. Dupuy's emphasis on qualitative variables in understanding combat, and we draw on his work for insights in numerous instances.

US Air Forces in FRG:

| Type Force | Readiness--Status Equip | Alert | # A/C | Assigned Theater | Enroute | Name of Unit |
|---|---|---|---|---|---|---|
| F-15 | 100% | 50% | 24 | CEur | - | 36TH-TFW/53RD-TFS |
| F-15 | 100% | 50% | 24 | CEur | - | 36TH-TFW/525TH-TFS |
| F-15 | 100% | 50% | 24 | CEur | - | 36TH-TFW/22ND-TFS |
| F-16 | 100% | 40% | 24 | CEur | - | 50TH-TFW/10TH-TFS |
| F-16 | 100% | 40% | 24 | CEur | - | 50TH-TFW/313RD-TFS |
| F-16 | 100% | 40% | 24 | CEur | - | 50TH-TFW/496TH-TFS |
| F-4P | 100% | 20% | 24 | CEur | - | 86TH-TFW/512TH-TFS |
| F-4P | 100% | 20% | 24 | CEur | - | 86TH-TFW/526TH-TFS |
| F-4P | 100% | 20% | 24 | CEur | - | 52ND-TFW/480TH-TFS |
| F-4P | 100% | 20% | 24 | CEur | - | 52ND-TFW/23RD-TFS |
| F-4G | 100% | 20% | 24 | CEur | - | 52ND-TFW/81ST-TFS |
| A-10 | 100% | 35% | 18 | CEur | - | 81ST-TFW/78TH-TFS |
| A-10 | 100% | 35% | 18 | CEur | - | 81ST-TFW/91ST-TFS |
| F-4P | 100% | 25% | 24 | CEur | - | 4TH-TFW/336TH-TFS |

Fig. 6--Illustrative air forces

- current location by RSAC *region* (e.g., Southeastern United States)
- nationality (the "owner" of the aircraft)
- theater to which the unit has been assigned (e.g., CEur)
- aircraft type (e.g., F-15, F-4, B-52)
- aircraft class (e.g., fighter, interdictor, and tanker)
- the original number of aircraft in the unit
- the number of surviving aircraft in the unit
- current alert status of the aircraft

For each aircraft type, CAMPAIGN also knows:

- the relative capabilities of the aircraft to perform various missions (air defense, escort, CAS, BAI, and interdiction) with either high- or low-tech munitions (for each mission, a baseline aircraft is identified with a value of one)

- the munitions that can be carried
- the nominal aircraft sortie rate
- the lift (of the various types) required to move a unit's logistical support
- aircraft range

The relative capabilities of aircraft account for qualitative differences of aircraft performance in various roles. For example, if an A-10 is the baseline CAS aircraft, then an F-4 might be evaluated as having a capability of 0.8 in the CAS role. These factors are used in air-battle adjudication, as will be discussed in Sec. VIII.

## IDENTIFYING FORCES

Each ground- and air-force unit is uniquely identified by name and nationality, as shown in Figs. 5 and 6. Nationality is required because there may be many units with the same designation (e.g., many 1st-Armd divisions, but only one U.S. 1st-Armd). The name syntax involves three parts: (1) a number or unit name, (2) a "-", and (3) a unit type designation. A unit may be identified as the 1-Armd or 1st-Armd (the "st" is automatically added by the input processor, but is optional). Capitalization is also optional (thus 1-Armd or 1-armd or 1-ARMD are all the same). Acceptable names include "Heb-Div", "1-TFW", and "4-MAW", whereas the following are not acceptable: "4 MAW" (no "-"), "MAB-4" (unit number and type reversed), and "1/2-Armd" (the "/" has a reserved meaning discussed in the next paragraph).[7]

Air- and ground-force names indicate a two-level command hierarchy, where the individual units, such as Pact divisions, are the "children" of an Army "parent," and NATO brigades are the children of a division parent. The child name *must always* be appended to the parent name after a "/", and cannot stand alone; thus, 1-Army/115-TKD is a legitimate

[7]This discussion of syntax pertains to Camper; the input processor uses blanks in the place of the "-" here and the "/" discussed below. Thus, a unit entered as the "1 Armd 2 Bde" in data file ground.sec becomes the "1st-Armd/2nd-Bde" in Camper displays.

name, whereas calling the same unit the 115-TKD would not work. The child part of the name follows the same syntax as the parent, involving a number or name, a "-", and a unit type. Thus an order can be entered for the USSR 1-Army/115-TKD (tank division), which would affect this single division, or for the USSR 1-Army, which would affect all of the divisions within this army.[8]

Alternatively, units can be identified by type, such as "armored" or "fighter" units, which will affect all such units in a particular area. All ground forces fit within the unit type "troops," and theater combat aircraft fit within the unit type "tacair." Aircraft can also be identified by aircraft type in some orders (e.g., F-15).

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[8]Some units in the input files ground.sec or air.sec are unnamed (a "-" replaces the name field). The input processor gives these units default names based upon unit type: for example, the first unnamed F-16 unit would be identified as the 1st-TFW in CAMPAIGN unless such a unit already exists for that nationality. Alternatively, if multiple units are aggregated and entered under the parent (e.g., a single entry in ground.sec for the 50TH-ARMD of Fig. 5), then the children are given default children names (e.g., 50TH-ARMD/1ST-BDE, 50TH-ARMD/2ND-BDE, etc.). Since these defaults are a function of the sequence in which the unit is entered, they can change as the data base changes. Users are cautioned to fully name any unit they plan to give specific instructions to over a series of data base changes.

# IV. PREPARATION FOR CONFLICT

CAMPAIGN presumes that in peacetime all air and ground forces are located at their normal bases with only a peacetime level of preparedness. Before these forces can be used in conflict, they must be appropriately prepared. This is done using the Alert, Mobilize, and Disperse orders.

## ALLIANCES AND CONTROL

Each country may choose to issue Mobilize and Alert orders for its own forces. However, CAMPAIGN also allows alliances to be formed through the use of the Side order. CAMPAIGN is basically a two-sided game, allowing players to side with Red, Blue, or themselves (remaining neutral); the default data base identifies a side for each country. Once a country sides with Red or Blue, it may also relinquish control of its forces to its alliance using the Control order. From that point on, all forces of that country fall under the alliance control structure headed by Red or Blue (e.g., Blue-controlled countries fall under NATO control), and thus Red or Blue are able to direct the use of all of these forces. Control may not be relinquished selectively, though some forces may be withheld by not assigning them to any combat theater (e.g., French home defense forces not assigned to CEur will not play in Central European combat until opposing forces enter French territory); still, since control is not selective, CAMPAIGN will not prohibit the Major Agent from making such assignments if it so chooses.

A country may abandon an alliance at any time. This can be done by retracting control of its forces (but still remaining an ally and granting some rights discussed in the next section) or by becoming completely neutral or siding with the opposition.

The user should give Side and Control orders early in a scenario to reflect the early establishment of alliances. If this is not done, orders to forces not under the alliance control will be null and void and will not be remembered when and if control is granted. This is a typical error in establishing order sets for CAMPAIGN, and when problems develop with allied forces, it is one of the first possibilities that should be examined.

## PREPARING GROUND FORCES

Preparing ground forces primarily involves the call-up of inactive forces and dispatch[1] from their bases toward embarkation points to move into the theater or forward positions in the theater. The Mobilize order directs ground forces to perform both of these functions, while the Disperse order is used to dispatch only forces that are already fullv mobilized (in cases where no reserve-type units are used). The Alert order currently does not affect the ground forces.

Both mobilization and the dispatch of ground forces from their bases requires time. Each individual force carries an indicator of its current mobilization level, and each force type (e.g., armor) has an associated rate at which mobilization occurs. For example, if armor units mobilize at 5 percent of total strength per day, and a particular unit starts at 20 percent mobilization, then it will require 16 days to fully mobilize. The dispatch of forces involves assembling and preparing equipment, and actually moving the unit; the data base carries a specific period of time required to perform these functions for each type of unit. If, for example, armor units require 1 day for dispatch, then the armor unit in the previous example would require a total of 17 days to mobilize and begin moving.[2]

Regular- or full-strength ready ground forces are usually assumed to be 100-percent mobilized even in peacetime, and thus do not require mobilization; they still require dispatch. Thus even regular ground

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[1]The term "dispatch" is used here to reflect the process of assembling and preparing equipment and moving the unit into formations preparatory to deployment. Dispersal from the base area itself is normally part of this process.

[2]In the real world, dispersal would actually proceed during mobilization. To model this, CAMPAIGN adjusts the actual mobilization rate to include dispersal. Thus, in the example, the mobilization rate for this unit would be adjusted to 4.7 percent per day so that the combined mobilization and dispersal would last 17 days.

forces are not immediately available for deployment or combat until some period of time after the appropriate orders have been given.

## TRAINING FOR GROUND COMBAT

Regular ground forces continually train and should be ready for combat. By comparison, reserve units (or combinations of regular and reserve forces) are usually not as well-trained, and thus may be less effective if committed to combat immediately after mobilization. This lower effectiveness may be due to lower/dated skill levels and to lower force cohesiveness (given that the personnel have not worked together on a daily basis).

Each unit within the data base has a "training effectiveness" multiplier that captures the combat effectiveness of that unit relative to an active unit (thus an active unit would normally have a training effectiveness of 1.0). The rate at which this effectiveness can be increased is different by government. There is no discrete order available to begin training; training begins automatically once mobilization has been completed.[3] In the previous example, if the armor unit started with 70-percent training effectiveness, and had a 3-percent per day training improvement rate, then starting on day 17 after mobilization the training rate would begin to increase, such that by day 27 the training multiplier would reach 1.0.

Training is one of the effectiveness multipliers used to determine effective equivalent divisions. It also affects cohesiveness:

$$coh = \frac{1+train}{2} * attrition\_factor$$

Thus, an armor division with 1.0 ED of equipment, a training effectiveness of 70 percent, no attrition, and all other effectiveness

[3]Alternatively, the analyst can change the mobilization or training levels of units to reflect covert mobilization or training. This is done by entering, for example, "set unit train 50-Armd US .8", which would set the training level of the U.S. 50th Armored Division (all three brigades) to 80 percent.

multipliers equal to 1, its cohesiveness would be 85-percent, and it would have an EED score of 0.6 (1 times 0.85 times 0.7). Moreover, CAMPAIGN requires a minimum level of cohesiveness for committing forces to an attack; if this threshold were 90 percent (set, for example, by typing "set landwar wtvd attk_pref 0.9"), then this unit would not be committed to an attack until its training level increased.

Each theater sets a minimum training threshold to be attained before forces are deployed from their bases. In the example mentioned above, if the theater involved had a training threshold of 85-percent, and the armor unit began training on day 17, it would not begin moving out of its base until day 22, when it reached 85-percent training effectiveness.

## PREPARING AIR FORCES

Because alerting aircraft is the critical path in major mobilizations of air units, CAMPAIGN currently focuses on the aircraft alert level.[4] An Alert order is used to set an ordered alert level, corresponding to the percentage of aircraft of the given type, which are on ground alert, prepared either for deployment or combat missions. Starting at a peacetime alert level, a higher-ordered alert level is approached at a fixed rate per hour. For example, if a fighter wing is at 10-percent alert and is ordered to 100-percent alert with an "alerting rate" of 3 percent per hour, then it will achieve 100-percent alert in 30 hours. Note that aircraft are included in CAMPAIGN at the primary aircraft authorization,[5] and thus alert levels on the order of 100 percent should be achievable; the maximum achievable alert level is stored by aircraft type in the data base.

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[4]While many air forces include substantial reserve components, the process of mobilizing these components is not currently included except for strategic airlift aircraft.

[5]The primary aircraft authorization is less than the number of aircraft on-hand and reflects the number of aircraft that should be available for combat at the start of a war (the remaining aircraft in the unit being somewhere in the maintenance cycle).

Besides maintaining a ground alert, it may be desired in some cases to establish an airborne alert. This is done using the Launch order, specifying the number of aircraft to stay airborne. CAMPAIGN then handles the related maintenance and support requirements. For example, if five F-15s are ordered to maintain an airborne alert, after an adjustment period some number of F-15s (e.g., ten) are removed from ground alert and held as unready, reflecting maintenance, mission preparation, or mission termination in order to support five aircraft airborne.

In some situations, it is also desirable to disperse aircraft, moving many of them away from their primary bases onto alternative airfields. This is done using the Disperse order, and specifying the percentage of full dispersal desired. CAMPAIGN then automatically rebases the aircraft, using a designated type of airfield.

# V. LOCATING AND MOVING FORCES

## ORDERING DEPLOYMENTS

To employ ground forces in combat, they must be assigned to the appropriate theater command[1] and deployed forward after being mobilized and dispatched.[2] Air forces not in a theater must also be deployed into the appropriate theater. A Deploy order automatically institutes alerting, mobilization, dispatch, and training for those forces to which it pertains, removing the requirement to issue a separate Mobilize or Alert order unless mobilization or alerting is to begin before a deployment decision.

Deployments can be performed in one of two ways. First, an explicit deploy order sends a specific unit to a specific destination; for example, one division from the Southeastern United States could be deployed to the Central Europe theater reserve. Second, to reduce the number of deployment orders required, a general Deploy order for *all* forces committed to a theater will send units to deployment objectives preassigned in the input data base; for example, the British reinforcements assigned to Central Europe and located at home would be tagged with a destination of the British corps sector, and would move toward that destination when a general NATO Deploy order is issued. The automatic deployment objective can be overridden by an explicit Deploy order; for example, the British reinforcements could be sent into the Dutch sector.

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[1]Within the RSAS, forces come under the authority of a commander when assigned to him, and not when they arrive in his area of responsibility. This is done during the alerting/mobilization process, so that lift assets devoted to the theater commander can be used to transport forces to that theater.

[2]In a surprise or similar situation, forces will enter combat when opposing forces reach their bases.

## MOVING FORCES

Air forces are moved from one regular region to another (for example, from US-NE to FRG, but not from US-NE to CEur). Alert aircraft are flown forward as soon as each squadron achieves its war-time alert state. CAMPAIGN does not constrain the movement of tactical air forces by the availability of tankers and staging bases, or the forward deployment of support.[3] Thus, air forces arrive much more quickly than they actually can; alternatively, the user can order unit-by-unit deployments according to a time-phased deployment list that more clearly reflects real-world capabilities, as in the RSAS war plans. Because of the level of aggregation of the model, the specific location of units within a region is not given; thus, when units move between two regions, the distance is either that of a specific air route, or the great circle distance between the centers of the two regions. Along air routes, movement can be constrained by overflight and landing restrictions imposed by third countries.

Ground forces are moved across one of two geographic representations in CAMPAIGN (as described in Sec. II): (1) regular geographic regions (as with the air forces), and (2) theater overlays (as shown in Fig. 3 above). Outside of theaters, only the regular regions are used; when ground forces are moved between two regions, the distance moved is either a routed distance based on a specific air or sea lane (see airlift and sealift below) or a ground route, or the great circle distance between the centers of the two regions. Within a theater of combat, movement becomes more complicated. Initially, all ground forces are located by country, though the data base also reflects their locations in the theater overlay. Thus, in peacetime, all units in West Germany are in region FRG, and not in the overlay CEur regions. Once preparation for combat or actual combat begins, all units within a theater that are ordered to participate[4] "pop" into the overlay. They

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[3]No degradation occurs to overall tanker availability during such deployments unless the user manually assigns some tankers to the theater and thus precludes their use in support of strategic nuclear forces.

[4]All forces ordered to deploy into a theater will pop into the overlay if they are in a country that the overlay covers. Additionally, forces of countries that have not turned over control to Red or Blue but are attacked will also pop into the overlay.

then move across the overlay, following the appropriate movement constraints.

Units that either move into the overlay from outside or move out of it headed for another location do so through entry points to the overlay at its back or edge. In some cases, entry may be constrained to a single point, allowing the user to establish appropriate constraints on the rate at which forces can move into or out of the theater. This process must be used with care since it imposes a somewhat arbitrary representation that may distort how units would move in reality.

## LOCATING GROUND FORCES IN A THEATER

Ground forces in the theater overlay may be located in several places: (1) first-echelon corps or armies, committed in a particular combat sector (referred to as an "axis"), (2) forces dug-in behind the FLOT, (3) second-echelon forces in an axis, and (4) theater or front/army group reserve. Forces may also be moving between these locations or into or out of the theater.

First-echelon forces are divided into forces on the forward line of troops (FLOT), and forces held in reserve. For example, if a 2-division NATO corps with three brigades in each division is a first-echelon corps, then each division would normally have two brigades on the FLOT and one in reserve. The FLOT in each axis is located a specified distance from the peacetime Red/Blue border, with all forces on the FLOT shown at this distance; the precise locations of the forces across the FLOT are not determined. Forces in reserve remain a settable distance (nominally 20 kilometers) behind the FLOT, and move with the FLOT. Only forces on the FLOT may participate in combat, except that artillery and attack helicopters held by reserve units may participate in combat. Forces on the FLOT may be excluded from combat if: (1) they are required to cover the flanks, or (2) there is insufficient "shoulder space" to fit all forces available on the FLOT. When subjected to attacks by tactical aircraft, forces on the FLOT are always struck by aircraft flying the close air support (CAS) mission, and forces in reserve are always struck by forces flying the battlefield air interdiction (BAI) mission.[5]

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[5]Note that this does not correspond to normal interpretations of CAS and BAI, since by this definition, all strikes against in-place

Forces may "dig-in" at a specific location behind the FLOT, awaiting either the FLOT to fall back upon them (at which time they join the first-echelon forces), or until a specified time limit elapses (when they become front/army group reserves, available for commitment). Forces that are dug-in *cannot* be committed to an assault by the ground commander model discussed below, and thus the use of this mission is often appropriate for follow-on or exploitation forces (by contrast, the ground commander model may commit second-echelon forces at will, as indicated below). Dug-in forces do not follow the FLOT, but stay in location and prepare at least deliberate defenses. Only one dig-in location is allowed per axis. Besides the location and time releases mentioned above, a dug-in force may be released by issuing a deploy order to it or by canceling its mission orders. Dug-in forces do not participate in ground combat (except for rear-area battles) and are not subject to either CAS or BAI, no matter how close they are to the FLOT (until the FLOT reaches them and they automatically become first-echelon forces); only interdiction or a specific "Strike"[6] order may affect them.

Second-echelon forces are so designated in the CAMPAIGN data base (in ground.sec); there is no interactive procedure for attaching a force to a second echelon. The second echelon is provided to simulate Soviet operational procedure, and thus would not normally be used by NATO forces. Second-echelon armies/corps follow the FLOT at a specified distance (nominally 50-70 kilometers). If a requirement develops for using these forces in the axis they are following, the ground commander model may release some element of the second echelon for use by the

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ground forces within the first 20 kilometers or so of the FLOT are considered CAS strikes (many of which--deeper than a few kilometers--would normally be considered BAI in conventional terminology). BAI is flown only against forces between about 20 and 50 kilometers behind the FLOT, or against these forces as they move forward. It is important to remember this in nonstandard use of terms in CAMPAIGN.

[6]The use of the term "Strike" with a capital "S" refers to an attack instituted by the Strike order. This may be a conventional, chemical, or nuclear attack, and takes precedence over any other tasking for the unit(s) designated to carry out the Strike.

first echelon; alternatively, the user may release the entire second echelon for use as a first echelon (by typing, for example, "set axis wtvd-2 second_ech").[7] Second-echelon forces are subject to Strikes and interdiction, but not to BAI or CAS (until moving forward), and do not participate in ground combat (except rear-area battles).

Frontal/army group and theater reserve forces are located in one of two ways. First. some of these reserves are given explicit locations when deployed into the theater (for example, a deployment location of "CEur-B/4/150" deploys a force to NorthAG--CEur-B--150 kilometers west of the inter-German border behind the British Corps--axis 4). These forces remain stationary until committed to combat or pushed back by the FLOT (CAMPAIGN attempts to keep them at least 70 kilometers behind the FLOT in their assigned axis). Second, forces without explicit deployment orders go to a single notional location for each theater or front/army group (for example, CEur reserves are 70 kilometers behind the FLOT on axis 4, while CEur-C--CentAG--reserves are 70 kilometers behind axis 7). These reserves may be drawn upon by the ground commander, who will attempt to reinforce an axis first from its front/army group reserve, second from the theater reserve, and third from another front/army group reserve (reflecting the transfer of reserves from one front/army group to another). Until committed, reserves do not participate in ground combat (except for rear-area combat) and are subject to Strikes and interdiction but not CAS or BAI.

Figure 7 shows the Blue ground forces as perceived by Red for targeting purposes in CAMPAIGN's targeting display (generated by typing "display targeting CEur"). It reflects that on-FLOT forces are targeted by CAS; axis reserves (stationary or moving) are targeted by BAI; and all forces further to the rear are targeted by interdiction or Strikes (Strikes may be targeted either against a specific force or against forces located within a specific zone, such as 4.15).

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[7]When a second echelon is committed, the first echelon is not automatically withdrawn. First-echelon forces may be individually withdrawn by deploying them back to front/army group reserve; they may then be withheld from the ground commander by giving them a dig-in mission somewhere in the rear.

| TARGETS FOR | EDs in AXIS 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| CAS: | 1.00 | 1.00 | 1.25 | 1.50 | 1.00 | 1.50 | 1.50 | 2.50 | 1.00 | 0.50 |
| BAI: | 0.50 | 0.50 | 1.00 | 1.00 | 1.50 | 0.75 | 0.75 | 1.50 | 0.50 | 0.25 |
| Moving: | 0.00 | 0.00 | 0.50 | 0.00 | 0.30 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Standing: | 0.50 | 0.50 | 0.50 | 1.00 | 1.20 | 0.75 | 0.75 | 1.50 | 0.50 | 0.25 |
| INTERDICTION: | | | | | | | | | | |
| Zone Name: | 1.12 | | 3.15 | 4.10 | 5.15 | | 7.12 | 8.11 | 9.11 | |
| Moving EDs: | 0.20 | | 0.30 | 0.00 | 0.10 | | 0.00 | 0.20 | 0.00 | |
| Other EDs: | 0.00 | | 0.00 | 3.00 | 0.00 | | 2.50 | 0.00 | 1.00 | |
| Zone Name: | | | 3.17 | 4.11 | 5.17 | | | 8.12 | 9.12 | |
| Moving EDs: | | | 0.90 | 0.00 | 0.50 | | | 0.00 | 0.00 | |
| Other EDs: | | | 0.05 | 0.50 | 0.00 | | | 0.80 | 0.40 | |
| Zone Name: | | | | 4.15 | | | | 8.13 | | |
| Moving EDs: | | | | 0.80 | | | | 0.00 | | |
| Other EDs: | | | | 0.00 | | | | 0.30 | | |
| Zone Name: | | | | 4.16 | | | | | | |
| Moving EDs: | | | | 0.00 | | | | | | |
| Other EDs: | | | | 0.10 | | | | | | |

Fig. 7--Forces in a combat theater

Before combat begins, first-echelon forces move to their axes and up to either the ordered position of the forces (if it is behind the border) or to the border. Once an Attack order is given, the border constraint is lifted and first-echelon forces simply move toward the ordered position (more will be said about combat movement in the next section).

Even during war, many forces will move based upon administrative (as opposed to combat) movement assumptions. In general, forces not committed to an axis follow the administrative deployment methodology. Moreover, if a first-echelon unit is ordered to another axis, it will also use the administrative deployment methodology. Note that the administrative movement rate differs (often significantly) from the (tactical) combat-related movement rates.

## MOVEMENT WITHOUT LIFT

Air forces usually fly to their destinations without using lift (except for their support elements), and if appropriate ground forces may deploy overland without using air- or sealift. Air-force squadrons deploy at the cruise rate of the aircraft, with some time allotted for refueling and maintenance enroute and at the destination before the aircraft are ready for use. Ground forces move overland at rates identified for each ground-force type. Once a ground-force moves into the overlay, movement is constrained by the throughput capacity of each zone. Currently, each ground force moves *as if* under its own power; no attempt is yet made to explicitly capture rail movements, for example.[8]

## AIRLIFT AND SEALIFT

If a unit requires strategic airlift or sealift, a ground unit first moves by ground to a place of embarkation. Air-force support units simply remain at their bases awaiting the arrival of airlift. When CAMPAIGN recognizes that an air or ground unit will require lift in the near future, it uses a resourcing routine to examine the lift assets available, makes assignments, and allows the forces to begin embarkation when ready, if sufficient lift capacity is available. The priorities for movement are: (1) personnel being matched with prepositioned equipment (e.g., POMCUS), (2) air-force support elements after their aircraft have already deployed, and (3) all other units in the order they are directed to deploy.[9] Lift capability and lift requirements are both measured in terms of personnel, regular cargo, and outsized cargo. All three factors play a significant role in airlift, while cargo tonnage is the dominant issue in sealift (sealift capacities are adjusted to equivalent tonnage in cases where volume is the true

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[8]However, with regard to Soviet movement into Eastern Europe, we have established a rate (in EDs per day) that forces can enter the theater in order to reflect the limited rail-system capacity. This factor is set at the entry point to the overlay from the Western Military Districts. This mechanism is explained in detail in the Zone table of the data file theater.sec.

[9]Different priorities can be given via the Deploy order.

constraint, and ships that would not move units efficiently are reserved for the movement of munitions and other supplies).

Each ground-force type is tagged with a default transportation mode (either by air or sea). However, in the Deploy order, the user may override the default mode.

Air and ground forces retain unit integrity when being transported, and thus each brigade, division, or squadron is moved as a unit. The time required for deployment includes embarkation and debarkation time, the time in transit, and (for ground forces) the time spent in moving to the embarkation site and in moving from the debarkation site to the deployment objective.[10] The route chosen can be affected by overflight and landing rights, causing significant variations in deployment time depending upon the cooperation of third countries.

## PREPOSITIONED EQUIPMENT

When most ground forces deploy from the homeland into the theater, they must take their equipment with them. However, some units have equipment prepositioned in certain theaters, and thus have to move only their personnel and some limited equipment. For example, POMCUS (Prepositioned Material Configured to Unit Sets) units that would deploy from the United States into West Germany are designated as special ground-force types in the data base, with a specification of the equipment they must take with them and the regular and outsized lift requirement of this equipment. When a POMCUS unit deploys to the CEur theater, only the personnel and required equipment are transported; the remainder of their equipment remains in the United States as war reserve stocks. When a POMCUS unit deploys to any other theater, it retains its on-hand equipment and is no longer distinguished as a POMCUS unit.

U.S. Marine prepositioning of equipment for Southwest Asia and Norway is handled in a similar manner.

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[10] POMCUS forces discussed below also have equipment breakout times specified by force.

## ALLIANCE ISSUES

Movement can be constrained by the lack of overflight, transit, or basing rights. These rights derive from alliances established by the Side order (see Sec. IV). They are exercised by a Major Agent (Blue or Red) and its allies. If deployments fail or take an excessive amount of time, the user should examine these rights. They can be granted or withdrawn by Permit and Deny orders.

"Transit" rights are for overland movement, and "overflight" rights are for movement of aircraft through a country's air space. When a Major Agent acquires these rights, all countries who side with him enjoy the same rights for their military forces. The RSAS strictly observes transit and overflight rights, looking for an alternative path when they are not granted rather than forcing transit; thus, if Egypt has refused to grant overflight for the United States when it is trying to move aircraft into Southwest Asia, then the United States must consider alternative routes. Since rights can be granted only to the Major Agent with which a country is siding, both Major Agents cannot have transit or overflight rights through any given country at the same time. No subsets of these rights or limitations to individual countries within an alliance are currently possible.

Basing rights allow the forces of the alliance with which one is associated to be based on one's territory. Thus, if France grants Blue basing rights, British aircraft could be moved to French bases and flown on combat missions from there. A deployment order will be rejected if the destination is a country that has not granted basing rights.

As a default, any country that has military forces other than its own based on its soil in peacetime is considered to be associated with the alliance those forces belong to, and to have granted basing, transit, and overflight rights to that alliance (though these may be revoked).

# VI. DECISION RULES FOR GROUND COMBAT

A major portion of the ground-forces model consists of rules used to simulate operational battlefield decisions. This section describes the character of these rules and how users interact with them.

## INITIATING COMBAT

Combat is initiated in a theater when one side or the other issues an Attack order, which simultaneously starts both air and ground combat. The Attack order affects ground forces in two ways. First, those ground forces assigned to the theater (and controlled by Red or Blue) that have not already been deployed into the overlay will be automatically deployed, though they will first mobilize and train, as appropriate.[1] Second, those forces already in the overlay begin to operate along their assigned axes, their movement controlled by the Position order. If the ordered position is in front of the forces, they will advance if possible; otherwise, they will try to hold their position. If the ordered position is behind the forces, they will withdraw to that position as quickly as possible. If the ordered position is the current position, the forces will attempt to hold their position. Thus, if the ordered positions are at or behind the border for both sides, the Attack order will only cause the air combat to begin.

As the forces move along their axes, they need not be in contact with opposing forces. For example, in peacetime, forces are usually located well behind their borders; in a surprise attack, the attacker will generally cross the border and advance some distance before coming into contact with opposing forces.[2] Even once forces are in contact, one side or the other may try to withdraw from contact (for example, to retreat to the next defensible line).

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[1]Thus, the model does not currently allow selective attacks within a theater where only some forces are committed, and all other theater forces are withheld at peacetime locations.

[2]In the surprise case, opposing forces that are encountered by the attacker will be forced into a withdrawal mode until they have sufficient strength (specifically, force density) to stand against the attacker given the existing terrain and defensive preparations.

## CHOOSING COMBAT ROLES

Forces that are not in contact with the opponent are allowed to move unimpeded toward their ordered positions until they encounter opposing forces. Forces in contact that are at their ordered position will automatically assume the role of defender (if the opponent also chooses to defend in this sector, then a stalemate ensues). Forces that withdraw to their ordered positions do so in a withdrawal posture. Finally, a force that is in contact but short of its ordered position must decide whether to attack and push toward its objective or whether to wait and defend for the present time, though it may choose to withdraw if its forces are inadequate to pose a meaningful defense.

For forces in contact, the choice to attack or defend is based on several issues. First, are the forces in this axis capable of attacking? Their ability to attack is a function of:

- the force type (e.g., units without significant amounts of armor usually will not act as attackers in Central Europe)
- force cohesiveness (i.e., units that are poorly trained or have suffered high attrition may be insufficiently cohesive to mount an attack)
- current position relative to neighboring axes (a halt may be called when exposed flanks become too long)
- the absence of recent battlefield nuclear strikes on this axis (such strikes temporarily halt combat)
- the presence of an opposing OMG behind friendly lines (the opposing OMG forces the units into a defensive operation against it)
- not out-running the logistics tail

If the forces are capable of attack, they then measure their total strength and their armored strength relative to that of the opponent on the FLOT and based on the given terrain,[3] and if both force ratios exceed minimums set by the player, the forces will attack. For

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[3]The ratio of attacker strength to defender strength is divided by a terrain adjustment factor (which is usually greater than 1), reflecting the advantages the defender is able to obtain by using the

sustained attacks, the force ratio must also exceed a threshold required to maintain an attack (this latter rule produces a pattern of assaults which, if they fail, lead to preparations for a next assault, a pattern commonly seen in actual ground combat). As suggested above, if any of these conditions fail, the would-be attacker chooses to defend for the present time.

In some cases, an attacker may choose to place only minimal forces in sectors of low priority. These forces may be insufficient to attack by the above criteria, and yet the attacker may wish to have them attack in order to fix and deceive the opposing forces. Such an attack is referred to as a pinning attack and is ordered by giving the appropriate axis a mission of "pin." This axis will then attack and advance against a defender in a delay or withdrawal operating mode, but "pin" without advancing against a defender in a hasty or otherwise prepared defense. This mission continues until the attacker has advanced to some objective, until some fixed amount of time has elapsed, or until canceled by the attacker.

The basic approach of the defender is to attempt to hold a prepared position, but to pull back to the next defensible position (employing a hasty defense where possible) if driven from the current preparations. Six alternative defensive approaches are available for each axis via the Mission order:

- **Default**. Defend when at or behind the ordered position and unable to attack. Do not withdraw unless a breakthrough is suffered or the ordered position is changed to be behind the current location. If not in prepared defenses, use a hasty defense. If short of the ordered position and able to advance (either unopposed or to attack if opposed), then do so.

- **Defend**. Similar to the default, except do not advance if possible. This difference is achieved by resetting the ordered position to the current position at all times. This mission will continue until a specified defensive position (in the rear) is reached or until a specified time occurs.

- **Defend-delay**. Defend while in prepared positions, but delay to the next prepared defensive line if out of prepared defenses

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terrain effectively for defensive purposes, such as cover and concealment.

and attacked. This mission will continue until a specified defensive position (in the rear) is reached or until a specified time occurs.

- **Defend-withdraw**. Defend while in prepared positions, but withdraw to the next prepared defensive line if out of prepared defenses, whether attacked or not. This mission will continue until a specified defensive position (in the rear) is reached or until a specified time occurs.

- **Delay**. Reset the ordered position to the indicated location in the rear and delay back to that position when attacked. This mission will continue until the ordered position is reached or until a specified time occurs.

- **Withdraw**. Reset the ordered position to the indicated location in the rear and withdraw back to that position whether or not attacked. This mission will continue until the ordered position is reached or until a specified time occurs.

Each of these missions except default may be canceled, in which case the mission returns to being the default. However, since some missions may cause forces to assume different postures (for example, a delaying or withdrawing force moves most of its strength to the rear and maintains only a covering force on the FLOT), it may take some time for the default mission to be reinstated.

All defensive missions other than the default can create a problem with the ground commander model, causing it not to work properly; in most cases, axes given such missions will not receive reinforcements from the ground commander. Thus, if these missions are used and reinforcements will also be required, the user should plan on directly deploying such reinforcements rather than expecting that the ground commander will do so.

Note that the delay mission is intended in part to simulate the kind of combat in a covering force battle, and thus should be used in such cases.

## STRATEGIC MANEUVER

It is currently infeasible to achieve fast execution speeds with a combat model allowing the full range of maneuver played, for example, in human war games using hex grids or other geometries. The failure to capture the details of maneuver is sometimes regarded as a fatal flaw of the fast aggregated models. However, most of the *effects* of maneuver can be reflected in CAMPAIGN indirectly. For example:

- Ground forces can be shifted laterally in CAMPAIGN by withdrawing them from combat on one axis and inserting them in another.

- If one nation's forces are better than another's because they use tactical maneuver more effectively (which is below the level of resolution of forces and models in CAMPAIGN), then its forces can be given a qualitative multiplier. This is undoubtedly appropriate for playing, say, Israel versus Egyptian or Syrian forces. It is not, however, obviously appropriate for the NATO/Pact situation.

- The *objective* of Soviet maneuver, breakthrough and exploitation, can be treated explicitly in CAMPAIGN. We do not follow the mechanisms of breakthrough in detail, because those would be highly variable and would require higher resolution and a stochastic treatment, but we do penalize NATO's effectiveness when conditions are ripe for a breakthrough (e.g., NATO defending forward with too few forces to cover the frontage adequately). We also examine, in excursions, the possible consequences of operational maneuver groups. Again, we do not model OMG actions in detail, but rather we monitor situations where OMGs could be used and estimate their possible consequences using Soviet thinking on the subject. Our estimates are a function of the defense's ability to bring up reserves and tactical air power, as will be described in more detail below.

- Unlike other models with which we are familiar, we treat a breakthrough as a discrete event as part of a process involving several *phases of battle*: assault, breakthrough, exploitation, and pursuit. We calculate attrition and rates of advance differently for the different phases.

- While forces may not strike in random directions or across flanks (except for envelopments), the current decision rules can force each side to cover their flanks sufficiently to negate the incentives for attacks across the flanks, where such flanks exist. Forces on the flanks also suffer modest attrition.

- An experimental strategic envelopment methodology is provided in CAMPAIGN to allow the user to directly play envelopments of opposing corps or armies in a largely parameterized framework.

Clearly, it is important--even essential--for some simulations to be conducted at a level of resolution and flexibility that allows explicit maneuver. There are several models available for that (e.g., IDAHEX) and several others under development (e.g., JTLS). However, in our view it is possible and appropriate to use more aggregated models such as CAMPAIGN for strategic-level analysis so long as that use is informed by experience with the more detailed simulations and history. We are hopeful that a version of CAMPAIGN can be developed with direct maneuver capabilities so that the calibration problem can be eased by having the maneuver effects isolated from other modeling issues.

## ATTACKING FORCE OPTIONS

The attacker in each axis is allowed to make two kinds of choices about his attack: whether or not to mass his forces in a subsector of the axis, and the intensity with which he attacks.

**Massing.** Massing is one of the principles of war; the attacker will almost always choose to mass. Massing allows an attacker to concentrate his combat capability in a narrow sector in an attempt to achieve a breakthrough. The sector of concentration is typically 6 to 10 kilometers wide,[4] compared to a normal axis width of perhaps 60 kilometers.

We have experimented with a number of procedures for modeling massing to date, but all are biased against the defender. The basic problem with such schemes is that the attacker's advantage is almost always transitory, since the defender will attempt to laterally move fires and reserves in a manner such as to thwart the massing. The real issue becomes one of how quickly this movement can be accomplished, and how well the sector being massed against can hold as forces move laterally.

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[4]See, for example, Allan S. Rehm and John F. Sloan, *Operational Level Norms*, Science Applications, Inc., SAI-84-041-FSRC, April 24, 1984, p. 2.4.

Given the size of the area in which this massing occurs, the resolution of the force interactions is below our level of aggregation, and therefore we have had to adopt a scripting approach to massing. We do this through a parameter that reflects the effectiveness of the defender in countering massing, and another parameter that reflects the differential velocity of the attacker while massing holds.[5]

We are hopeful that some advance beyond these crude mechanisms will be possible, but have provided them as an interim solution until a more agreeable methodology can be achieved.

**Combat Intensity.** Combat may be fought at either nominal or high intensity at the discretion of the attacker on a particular axis. High intensity occurs on "main thrust" axes that have at least a certain force ratio, this ratio set by the player. At high intensity, attrition, movement, and logistics consumption increase in accordance with analyst-controlled parameters. High intensity can only be maintained for a few days.

## PREPARING DEFENSES

A defender is able to establish a variety of different defenses, depending upon operational choices, time, and the availability of engineering resources. We identify four different kinds of defensive postures in terms of increasing effectiveness: (1) a hasty defense, (2) a deliberate defense, (3) a prepared defense, and (4) a fortified defense. A hasty defense can be established quickly, involving only a small amount of preparation time, and is intended to slow an advancing foe to the extent possible while moving back through areas without prepared defenses. When the defender is not within deliberate, prepared, or fortified defenses, he employs a hasty defense under the default mission. The other forms of defense require some degree of preparation. Deliberate defenses are built by a force whenever it

[5]A large number of internal RAND memos document our debate on this subject and this tentative resolution. Those interested in this issue are invited to discuss it with Paul Davis, Bruce Bennett, or Robert Howe of RAND.

establishes a defensive line and is not under attack (either being out of contact with the opponent, or in a stalemate condition). Prepared and fortified defenses must be ordered by the defender and assume the use of engineers within an overall theater availability level. The degree of defensive preparation and its depth are determined by construction rates and are a function of the time available for preparation and the militarily usable width of the area being defended.

## OTHER COMBAT RULES

Other rules relate to handling flanks and operational maneuver groups (OMGs). To prevent flanks from growing too large, each side sets an absolute limit on the size of flanks that it will tolerate. When this limit is reached, an attacker must stop, or a defender must withdraw. Each user also sets a relative density requirement for forces on the flank; for example, Blue might require that forces on the flank are at least 50 percent the density of his frontal forces. Forces diverted to the flanks come from both axes sharing the flank based upon a relative ability (frontal density) to cover the flank. Only force on the FLOT may cover the flanks. The diversion of forces to the flanks can leave a sector ripe for OMG insertion or an eventual breakthrough.

The simulation of OMGs, while quite aggregated, involves three components: (1) criteria for committing the OMG, (2) determination of whether a particular commitment is successful, and (3) determination of the effects of OMG commitment. Of these three, the first fits in the category of operational combat rules. This rule requires that before an OMG can be committed, the opposing forces must be in contact with each other, with one side attacking and the other defending. The attacker then will commit an OMG if: (1) the attacker has penetrated any prepared (non-hasty) defenses, (2) no other OMGs are currently operating on the axis, (3) a force given the OMG mission is available to become an OMG, and (4) the attacker has achieved a threshold force ratio. With regard to the third point, CAMPAIGN currently assumes that a force is specifically trained and prepared to carry out the OMG function, and that such forces are tagged for the OMG mission; OMG forces are withheld from normal combat so that they can be prepared for commitment at an appropriate point in time.

## STRATEGIC ENVELOPMENT

The experimental strategic envelopment model within CAMPAIGN requires that the user specifically order each envelopment. An envelopment may involve a single pincer pushing toward a physical barrier (such as the North Sea) or two pincers pushing toward each other. When ordering the envelopment, the user may specify that it is to begin immediately or that it is to wait until some overall exposure has been achieved on the enemy flanks facing each pincer (when this is achieved, the envelopment then automatically begins). The player must also specify which forces are to penetrate into the enemy rear and in which axis each will assume a blocking position. Other rules associated with envelopments are discussed in the next section.

## GROUND COMMANDER MODEL

There is a fine line between strategic decisions and troop control. Ideally, the human player or automated model should make *all* major decisions down to and including important theater commander decisions such as how to allocate reserves among sectors. However, in practice, this allocation requirement is burdensome. Experience in war gaming has taught us that many players like to be able to play some forces in great detail, while other players would prefer that the operations of forces be handled by the computer after specifying some simple guidance.[6] CAMPAIGN accounts for the former preference by providing detailed orders and for the latter by providing a set of "rule-based" support packages constituting the Ground Commander Model (GCM). With regard to ground combat, two levels of GCM are provided: (1) the Theater Commander and (2) the Axis Commander. Currently, the theater commander is an option available to the player and may be suppressed if so desired (allowing the user to play these roles through the normal CAMPAIGN orders); however, the axis commander must be run in an automated mode since appropriate CAMPAIGN orders do not exist to allow human players to handle its roles.

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[6]Indeed, for strategic-level (theater) studies, it is inappropriate to dwell on operational- and tactical-level detail.

The current GCM rules are not designed to optimize force use, but rather to reflect the kinds of operational decisions we would expect to see real commanders make. Thus, in the development process, the rule writers (Carl Jones and Robert Howe) sought to reflect how human experts play manual war games, focusing on the Central European theater. These rules already reflect specific Soviet and NATO operational practices to some extent, and we plan improvements in this area.[7] Moreover, many of the rules are generic and could probably be applied anywhere in the world, though some rules may have to be altered in considering other theaters.

**The Theater Commander.** The theater commander model takes as inputs: (1) choices to attack or defend in each axis, (2) priorities among the axes (the priorities may be: main thrust, high priority, and low priority), (3) rules on where forces of specific nationalities can be sent, (4) phase lines that are attack objectives when on the offensive and defensive hold lines otherwise, (5) a minimum theater reserve requirement and a maximum rate of force allocation, and (6) various requirements for and rates of allocation of supplies. The axis priorities are used when allocating scarce resources (reserves, war reserve materials, and logistical support), setting combat intensity, and other similar issues. The failure of an attacker to reach a phaseline, or a defender's being pushed back to a phaseline enhances the relative priority of axes for allocation of forces and supplies.

Based upon these inputs, force assignments and logistics are handled. With regard to forces, units may be committed from the theater reserve to specific axes, and corps/army boundaries may be shifted by moving units from one axis to a neighboring axis. In some cases, units are also pulled from an axis in order to reconstitute a reserve.

With regard to logistics and war reserve materiels, as long as supplies are adequate and no bottlenecks develop, these materiels are allocated on demand. Once supplies start to dwindle, however, shipments are made based upon the priorities established for the axes. Moreover,

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[7]At present, the GCM does not *explicitly* reflect Soviet Front structures or the detailed dynamics of echeloned movement.

each axis is allowed to maintain a nominal amount of supplies and may reorder supplies when they reach a certain point; the higher the axis priority, the more supplies that may be held, and the higher the resupply point.

**The Axis Commander.** The axis commander is responsible for determining which of the brigades or divisions within the first echelon will fight on-FLOT and which will be held in axis reserve. In doing so, it begins with a default logic (specified by the user) that, for example, two brigades of every division should be up front and one held in reserve. As attrition occurs, the axis commander will attempt to rotate brigades between combat and the reserves in order to allow units to reconstitute themselves. However, if combat power becomes too limited to cover the given terrain, the axis commander may be forced to commit much of his reserves and eventually to withdraw either before or after suffering a breakthrough.

# VII. ADJUDICATING GROUND COMBAT

Once the forces have determined how they will operate in each axis, the ground-combat model adjudicates the combat that results.

## PHASES OF COMBAT

The phases of combat are simulated in CAMPAIGN as indicated in Table 5. During the preparation phase, neither side attempts to advance against the other, but both carry out active reconnaissance and related activities against each other, producing the stalemate results in CAMPAIGN. During a stalemate phase, both sides automatically prepare some depth of a deliberate defense and may develop either a prepared or fortified defense if so ordered.

Once an assault begins, the defender normally uses one of these three types of defenses or a meeting engagement develops if for some reason both sides attempt a simultaneous assault. Later in a battle, once forces are pushed out their defensive positions, the assault may continue against a hasty defense, a delay, or a withdrawal, depending upon the choices of the defender. An assault may continue for only a

Table 5

PHASES OF COMBAT AS REPRESENTED IN CAMPAIGN

| Phase | CAMPAIGN Postures |
|---|---|
| Preparation | Stalemate |
| Assault | Deliberate, prepared, fortified, hasty, meeting |
| Assault support | Pinning |
| Breakthrough, exploitation | Breakthrough (pursuit) |
| Pull-back | Delay, withdraw |
| Termination | Stalemate, out-of-contact |

few hours or for many days; however, it will eventually be adjudicated in one of three ways: (1) a breakthrough occurs, (2) the defender holds and a stalemate ensues, or (3) the defender pulls back.

A breakthrough occurs in CAMPAIGN when the defender is no longer able to cover even a specified combat frontage in a given axis, rather than as a stochastic event as would occur in the real world.[1] When a breakthrough does occur, there are two procedures for capturing its effects. First, a one-time attrition penalty is assessed to the defender (losses associated with the collapse of the defending forces). Second, an exploitation phase begins with appropriately high defender losses and continues until the defense is able to establish a cohesive line of defense.

An assault fails in CAMPAIGN when the attacker either adjusts the position order to the current FLOT location (indicating that the force is no longer ordered to advance) or is no longer able to meet the force ratio and other criteria required for an attack. The attack then terminates, and the status shifts to a stalemate condition.

As suggested above, an assault may transition into a pull-back in one of two ways. First, the defender may choose to withdraw or delay back to some position. Second, a defender may choose to withdraw or delay in between prepared defenses, in which case the pull-back is initiated when the on-Flot forces are pushed out of a defensive position. Eventually, a pull-back can transition either to a stalemate (if, for example, the attacker reaches his ordered position) or to another assault (if the defender withdraws into a prepared position in which he is capable of making a stand, or if he is reinforced sufficiently to pose a hasty defense in a nonprepared area).

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[1]This frontage includes consideration of terrain and defensive preparations. Since CAMPAIGN is a deterministic model, this kind of approach was required. Alternatively, CAMPAIGN allows the controlling analyst to cause a breakthrough at any chosen point to test the robustness of the results against stochastic events.

## ADDITIONAL ASPECTS OF THE GROUND COMBAT FRAMEWORK

Besides the factors mentioned above, two further factors affect combat results:

**Terrain**. Three aspects of terrain are considered in our modeling: (1) how terrain effects force movement (trafficability), (2) the degree to which terrain facilitates defense, and (3) the extent to which the terrain channel force movements (for example, requiring forces to travel over only a few roads because of mountains or swamps or the density of forests). Trafficability is measured as a fractional multiplier (e.g., 0.75) times the nominal force movement rates. Defensibility is measured as a force ratio divisor (such as 1.25) that reduces the advantage of the attacker in particular terrain. Only some preliminary work has been completed on the third factor, which is modeled as a limited road network, but for which only incomplete data are available. We also intend to indicate explicitly where major urban areas are located, allowing the attacker to bypass (but surround) these areas, or to fight through them in a qualitatively different manner.

**Timing of Combat**. Attrition and movement rates in this model are specified in daily terms, using figures based loosely on historical battles involving a combination of day and night operations (predominantly day). Combat is adjudicated in six 4-hour periods each day. Each period will be explicitly identified as a day or night period. The controlling analyst specifies the fraction of combat that occurs in each period.[2]

## GROUND FORCE ATTRITION

There are three basic sources of attrition to ground forces: (1) ground-force engagements, (2) conventional attacks by aircraft (including attack helicopters), and (3) nuclear attacks. Note that CAMPAIGN measures attrition to equipment, not personnel (at least for

[2]For Central Europe, days may be 8, 12, or 16 hours long. In order to simplify the interdiction model, night in Europe always begins at 8 p.m. Thus, a 12-hour day begins at 8 a.m., whereas an 8-hour day begins at noon.

the present); therefore CAMPAIGN also includes repair functions to reflect the fact that many weapon systems that have been damaged may be returned to effective use once again.

**Ground Force Engagements**. In these engagements, attrition is nominally a function of: (1) the type of engagement (based in part on the phase of battle), (2) defender density, (3) the force ratio (FR), and (4) the terrain (terra). The first, third, and fourth factor are captured in the defender's loss rate (DLR) and the exchange rate (ER)[3]:

$$MFR = FR/terra$$

$$DLR = .043 * (MFR/pal)^{.64}$$

$$ER = 2.5 * (MFR/pae)^{-.57}$$

where MFR is the (terrain) modified force ratio (in some cases MFR is also called the adjusted force ratio). The values for pal, pae, and terra are given in Table 6. Note that the "terr" value[4] is a function of the actual terrain, enhancing the relative strength of the defender as discussed above, while terra reflects whether it is applied or set equal to one (in cases where neither side gains a relative advantage from terrain). Using these equations and parameter values, Table 7 shows the estimated attrition at some nominal adjusted force ratios.[5] As indicated in this table, these numbers are for normal intensity

[3]Experienced analysts, especially those familiar with Lanchester equations, may find this formulation a bit unusual. The form of the equations was derived by fitting curves used in several ground combat models, while the parameters (the constants for DLR and ER and the pae and pal values) were derived to reflect historical combat attrition data. Those interested in more details on this formulation are invited to contact the authors.

[4]Terr normally ranges from 1.1 to 1.5 for Central Europe.

[5]For either the meeting engagement or the stalemate postures, the attacker is defined as the stronger of the two parties simply for accounting purposes. These values are approximate in that the attacker attrition shown in each case assumes no terrain adjustment to the force ratio. Note also that the attacker loss rate is adjusted for a meeting

Table 6

PARAMETERS USED IN
ATTRITION EQUATIONS

| Type of Battle | pal | pae | terra |
|---|---|---|---|
| Breakthrough | 0.8 | 0.2 | terr |
| Withdrawal | 2.0 | 0.7 | terr |
| Delay | 3.0 | 2.0 | terr |
| Hasty | 1.0 | 1.0 | terr |
| Deliberate | 1.5 | 2.5 | terr |
| Prepared | 2.0 | 4.0 | terr |
| Fortified | 3.0 | 7.0 | terr |
| Stalemate | 20.0 | 0.2 | 1.0 |
| Pinning | 8.0 | 0.45 | terr |
| Meeting | 0.75 | 0.15 | 1.0 |

combat, with no OMGs operating on either side. As a default, high intensity combat increases these figures by 50 percent.

Besides the attrition shown in Table 7, a defender who suffers a breakthrough is assessed a one-time attrition penalty (currently 10 percent) to reflect the results of local encirclements and collapses associated with the breakthrough.

Finally, forces on the flank receive a fixed amount of attrition (nominally 1.5 percent per day, which can be changed, for example, to 4 percent for CEur by typing "set landwar ceur flank_attrit 0.04"). Setting this parameter relatively high will penalize a side for maintaining large flanks.

**Conventional Air Attacks.** The current model presumes that aircraft may attack ground forces at four basic kinds of locations: (1) on the FLOT (CAS), (2) in axis reserve immediately behind the FLOT (BAI), (3) in the front/army group or theater reserve areas (interdiction), and (4) enemy forces operating in the friendly rear

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engagement at a 1:1 ratio to equal the defender rate, which is a bit higher than the equations above would predict.

(e.g., airborne forces or OMGs). Helicopters attack forces only on the FLOT. Each type of attack is handled somewhat differently.

Attacks against forces on the FLOT are performed by CAS mission aircraft, helicopters, and by aircraft in the interdiction mission that have been ordered to strike at the front (target type THTR_cas). All fixed-wing aircraft are given a qualitative capability to perform such a mission relative to a standard CAS aircraft (for example, relative to an A-10 on the Blue side); the same approach is applied for helicopters relative to a standard helicopter (though the standard helicopter may have different kills per sortie than the standard CAS aircraft). The total number of successful sorties, the average quality per sortie, the

Table 7

SAMPLE ATTRITION RATES

(Percent/Day*, Normal Intensity, No OMGs)

| Modfd Force ratio | Posture | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Break | Withd | Delay | Hasty | Delib | Prep | Fort | Stale | Pin | Mtg |
| Attacker | | | | | | | | | | |
| 1 | 5.0 | 5.6 | 7.9 | 10.8 | 14.0 | 15.2 | 16.1 | 0.6 | 1.8 | 5.2 |
| 2 | 2.6 | 3.0 | 4.1 | 5.6 | 7.3 | 8.0 | 8.5 | 0.3 | 0.9 | 2.3 |
| 3 | 1.8 | 2.0 | 2.8 | 3.9 | 5.0 | 5.5 | 5.8 | 0.2 | 0.6 | 1.6 |
| 4 | 1.4 | 1.6 | 2.2 | 3.0 | 3.9 | 4.2 | 4.4 | 0.2 | 0.5 | 1.2 |
| Defender | | | | | | | | | | |
| 1 | 5.0 | 2.8 | 2.1 | 4.3 | 3.3 | 2.8 | 2.1 | 0.6 | 1.1 | 5.2 |
| 2 | 7.7 | 4.3 | 3.3 | 6.7 | 5.2 | 4.3 | 3.3 | 1.0 | 1.8 | 8.1 |
| 3 | 10.0 | 5.6 | 4.3 | 8.7 | 6.7 | 5.6 | 4.3 | 1.3 | 2.3 | 10.4 |
| 4 | 12.0 | 6.7 | 5.2 | 10.4 | 8.1 | 6.7 | 5.2 | 1.5 | 2.8 | 12.6 |

* These are loss rates to combat equipment (EDs), not personnel. They are rounded to tenths and do not include repairs, which are modeled separately.

posture of the ground force attacked, the damage caused by a nominal sortie against that posture (in vehicles killed per sortie), and the relative mix of armor and infantry on the FLOT determine the damage done by each set of attacks. The attrition caused to helicopters is a function of a loss rate set per sortie, which is in turn scaled up or down based upon the current strength of opposing organic air defense (as compared to a baseline capability).

The axis reserve is attacked by BAI mission aircraft and interdiction mission aircraft ordered to strike axis reserves (target type THTR_bai). The damage calculations in this area parallel CAS damage, except that a separate set of effectiveness values are used for qualitative assessments of the aircraft and the nominal damage per sortie given the posture of the opposition.

Attacks against the reserves can be performed by interdiction mission aircraft (target type THTR_deep). Damage is based upon an intelligence factor associated with being able to locate reserve forces and an effects factor (by type of aircraft) that indicates the level of damage that can be done.

Finally, enemy forces in the friendly rear can be hit by interdiction mission aircraft (target type THTR_insert). Damage is handled according to the CAS formulation, using a special kills/sortie factor for forces in the friendly rear.

**Nuclear Attacks.** Nuclear attacks can be delivered against the same kinds of forces as conventional attacks, though this methodology considers both an intelligence factor (i.e., whether or not the attacking weapon can locate opposing forces) and a density factor (which allows opposing forces to disperse if they anticipate nuclear attack). That is, while conventional attacks tend to be focused on individual vehicles or small groups of vehicles and troops, nuclear attacks tend to damage a much larger area and may effect whole units within that area.

Nuclear attacks also affect the cohesiveness of the forces. This effect involves: (1) no combat on an axis that has suffered a nuclear attack for some period of time thereafter (nominally six hours; changed to one hour, for example, by typing "set force nucdelay 1"), and (2) a reduction in the cohesiveness of the individual forces struck by nuclear weapons (which is often sufficient to stop an assault, for example, until a new echelon can be committed).

**Attributing Attrition.** Ground-force attrition is normally calculated on an axis basis.[6] This attrition is then attributed to the ground forces using a "cascading" scheme between forces with the same parent, which causes some forces to receive relatively more attrition, and some relatively less, the pattern that would be expected from massed attacks. Forces that already have relatively high attrition tend to receive relatively more of the incremental losses, under the presumption that they are the forces more likely to be part of the massed attack (from either attacker or defender perspective).

**Repair and Recovery.** Many of the weapons damaged will be repairable either at the axis or theater level. CAMPAIGN calculates a fraction of equipment that cannot be repaired and a fraction of otherwise repairable equipment lost by a force being pushed back; the remainder is divided among axis and theater repairs. Equipment repairable at axis level is immediately returned to operational inventories. Equipment requiring theater level repair is placed in a repair pipeline and emerges at an appropriate point into the war reserve material stocks for reallocation to units, as required.

## MOVEMENT

FLOT movement within the current model is a function of the terrain, the type of engagement, the force ratio, and the force density. Movement can be affected by air strikes, operational maneuver groups, and the intensity of conflict, among other issues.

**Basic Movement.** When forces are in contact, their movement is a function of both the role assumed by each side (attacker or defender) and the type of defense being posed, producing an engagement type. The values in Table 8 illustrate the movement rates currently used for Central Europe (slower rates are used in Korea because of the more difficult terrain there). When forces are not in contact, the FLOT is

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[6] The exception is that individual forces can be targeted by Strikes.

Table 8

MOVEMENT RATES IN (KM/DAY)
FAIR TERRAIN

| Engagement Type | Mod. Force Ratio 1 | 3 | 5 | 7 |
|---|---|---|---|---|
| Breakthrough | 19 | 38 | 53 | 60 |
| Withdrawal | 30 | 45 | 53 | 60 |
| Delay | 8 | 23 | 38 | 53 |
| Hasty | 3 | 14 | 35 | 52 |
| Deliberate | 2 | 10 | 28 | 41 |
| Prepared | 2 | 8 | 22 | 27 |
| Fortified | 1 | 5 | 13 | 18 |
| Stalemate | 0 | 0 | 0 | 0 |
| Pin | 0 | 0 | 0 | 0 |
| Meeting | 5 | 20 | 48 | 68 |

able to move at the maximum combat speed (assumed to be 100 km/day in Central Europe), which is then adjusted by terrain and other factors (in fair terrain, the maximum velocity is 75 km/day).

Terrain affects movement in two ways. First, terrain multipliers adjust the force ratio in cases where one side is the attacker and the other is the defender, as described for attrition above. Second, once a nominal movement rate is calculated, a terrain multiplier is applied to reflect the combat trafficability of the terrain (for fair terrain, a multiplier of 0.75 is used, as in Table 8).

**Defensive Density**. Defensive density has four ranges in which it affects movement. First, for densities greater than the "hold" density, the basic movement rate is multiplied by a factor less than 1.0 (generally in the range of 0.1 to 0.5), reflecting the fact that a high density defense is extremely difficult to penetrate. Second, between the "hold" and "minimum" densities, the basic movement rate holds. Third, between the "minimum" and "breakthrough" densities, the attacker achieves a mixture of the nominal velocity and the breakthrough velocity (more of the latter the closer the defender gets to a breakthrough).

This reflects the ability of the attacker to achieve local penetrations against such a density and the relative difficulty for the defender to counter such penetrations when spread thin. Fourth, below the "breakthrough" density, the defender suffers a breakthrough and is thrown into the breakthrough mode for movement calculations.

**The Effect of Interdiction on Movement.** Air attacks on advancing forces also affect the movement of those forces. Currently, only the defender's CAS, BAI, and helicopter sorties have such an effect on FLOT movement.[7] A specified number of sorties by the defender's CAS, BAI, and helicopters are presumed to be able to pin-down attacking units of a given size for a given amount of time (cas_hr_delay for equivalent CAS sorties, bai_hr_delay for equivalent BAI sorties, and helo_hr_delay for equivalent helicopter sorties); thus each equivalent sortie delivered can slow the advance of a division by some amount of time. For example, if 20 A-10 sorties are required to stop an equivalent division's advance for 1 hour, cas_hr_delay equals 0.05. It is further assumed that this delay really pertains only to cases where forces are moving largely by road rather than in direct, heavy combat, so that an attacker cannot be slowed below a certain minimal advance rate (min_rate). Thus, if a force of size EDs would otherwise advance at rate "speed," it will be slowed by CAS to rate "adv_rate" (advance rates specified in daily terms):

$$\text{adv\_rate} = \text{speed} * \max\left[\min(1, \text{min\_rate}/\text{speed}),\ 1 - \frac{\text{eq\_sorts} * \text{cas\_hr\_delay}}{24 * \text{EDs}}\right]$$

The effects of CAS, BAI, and attack helicopters are all added together to determine the effect on the advance rate. Generally, the effects of CAS and attack helicopters are expected to be greater than the effects of BAI, which because CAMPAIGN assumes it is targeted against reserve brigades or divisions, is really only slowing the tail of the advance.

[7]The presumption is that the attacker's CAS and BAI aircraft and helicopters affect future movement by altering the force ratio rather than having an immediate FLOT movement-enhancing effect. Obviously, this approach oversimplifies the problem, and we are working on a more realistic approach.

## INTEGRATED ATTRITION AND MOVEMENT

An experimental integrated attrition and movement methodology has been tested in CAMPAIGN to combine affects such as density and interdiction into a single framework. RAND has not yet had sufficient opportunity to tune this method, and thus this is not the default methodology within CAMPAIGN. Once further work has been completed in this area, the results will be documented and made available for prospective users.

## OTHER ISSUES

**Surprise.** Surprise attacks have the effect of increasing the attacker's advantage, especially early in an attack. A special surprise multiplier (which increases the force ratio, as mentioned above) is used when the analyst determines surprise has been achieved. This multiplier remains for a period of time fixed by the analyst.

**Envelopments.** For an envelopment to be initiated, it must meet a variety of criteria including:

- The flank penetrations specified in the envelop order have been achieved. These positions must reflect an advance by each pincer base (a pincer base cannot be ordered to withdraw to reach its envelopment initiation position).
- At least one blocking force has been assigned to each axis to be blocked, and all blocking forces are in position to begin penetration (blocking forces must be reserves brought in to serve as the envelopment pincers, and not first-echelon forces used to set up the pincer bases).
- The attacker must have a cohesive defense or offense operating on all axes to be blocked (including no withdrawals ongoing).
- The time limit for the envelopment has not elapsed.

When all conditions are met, the user will be notified that the envelopment has begun. Until that time, an examination of the axis display (e.g., "display axis wtvd5") for the one or two pincer bases will generally explain why the envelopment has not yet begun. The pincer bases will advance to the indicated initiation positions and then wait at those positions until the envelopment can begin.

When the envelopment begins, the blocking forces move as pincers into the enemy rear. The envelopment is considered completed when all blocking forces have assumed their positions; the progress toward this goal can be observed via the envelopment display (e.g., "display envelopment wtvd"). As the pincers begin to close, the opposing forces may choose to begin to withdraw from the envelopment. In this phase, their movement may be relatively rapid, as a cutoff has not yet been achieved. Once the envelopment is complete, the withdrawal slows to an enveloped rate, and then to a much slower rate as the entrapped forces approach the blocking forces and the "mop-up" begins. Depending upon the relative strength of the envelopers and the forces enveloped, the forces enveloped may be entirely lost or they may break through the blocking forces to establish a new, clear FLOT.

Currently, defending forces cannot break into an envelopment, nor can they attempt to break out through a flank. Moreover, density rules do not apply to envelopments. As this methodology matures, these and other factors will be added to our considerations.

**Operational Maneuver Groups.** The effects of OMGs are determined in two steps: (1) whether a particular commitment is successful, and (2) what effects commitment has.

An OMG insertion will fail if an adequate gap has not been opened by the on-FLOT forces, which is simulated by requiring an on-FLOT adjusted force ratio (not including the OMG) of at least some threshold (e.g., 4:1). The OMG insertion may also be defeated by some combination of defender reserves and CAS sorties (which are measured against a fixed requirement). If the OMG fails (that is, if the defender is able to meet these criteria), then the OMG suffers 50-percent attrition and is withdrawn.

If the OMG succeeds, it is assumed to move forward a specified distance. It then becomes part of a rear-area battle.

**Rear-Area Battles.** A force may enter a rear-area battle either as an OMG or as an airborne or air-assault force in RSAS 3.0. These forces assume a position in the rear of the opposing FLOT. Over time, it is assumed that they engage the axis forces (both reserves and forces on the FLOT) in the rear area they are located, suffering a fixed attrition rate and inflicting attrition. Forces can operate in the rear for a number of days and then perish unless the FLOT catches up with them.

# VIII. THEATER AIR OPERATIONS

The process of alerting aircraft and deploying them has been discussed in previous sections. This section describes how aircraft are used in theater combat.

## AIRCRAFT CLASSES

The aircraft classes used in CAMPAIGN correspond directly with the roles that the aircraft can perform. Three basic theater aircraft roles are currently recognized: air-to-air, CAS, and interdiction.[1] Aircraft that perform only the air-to-air role are designated the "fighter" class; aircraft that perform only the CAS mission are designated the "CAS" class. Aircraft classes that perform only the interdiction role are differentiated by range: interdictors or fighter bombers (Blue versus Red terms), medium bombers, and heavy bombers. Finally, the "multi-role" class is provided for aircraft that can perform all three roles. All combat aircraft must be entered as fitting into one of these classes.

## AIRCRAFT BASING AND SORTIE RATES

Each type of aircraft is capable of performing a certain number of sorties per day, based upon the maintenance and related activities that must go on between sorties. The total sortie level may be further limited by:

- Non-alert aircraft
- Overcrowding of airfields
- Damage to airfields

[1]Currently, only direct combat roles are included. Other roles such as reconnaissance, electronic warfare, intra-theater lift, and other forms of surveillance will be added in the future. Meanwhile, aircraft can be entered in classes corresponding to these roles, but the model does not simulate the operation of such aircraft.

- Aircraft dispersal
- An analyst multiplier by region or owner

Thus, if air bases are heavily damaged or deployments to them exceed the ability of the bases to generate sorties, the air-base sortie generation capability will become the dominant factor in determining the number of sorties flown. If air bases are damaged, appropriate repair functions are used to reestablish the functions of the bases over time.

To support the determination of sortie potential, CAMPAIGN's data base contains information about the number of air bases by owner in each world region, and their ability to support sorties. Air-base data in each region is resolved to 8 types of bases as shown in Table 9. Each of these base types can be separately targeted, but individual bases within each type are not represented.

The initiating data base for a scenario specifies the peacetime basing structure for the world's air forces. When air forces receive orders to deploy to other regions, an "enbasing" model simulates the decision process involved in deciding where in the destination region the force should be based. The enbasing model will not permit forces to be sent to regions in which no space is available to accommodate the force. For example, if the region Tunisia is described as having no bomber bases or major civilian airfields, B-52 forces would not accept orders to deploy there.

At some point in a scenario, a player may choose to disperse his aircraft in one or more areas in order to reduce their vulnerability to attack. This is done through the use of the Disperse order, which indicates a percentage of full dispersal that the user wishes to achieve. Even at full dispersal, some fraction of the aircraft (about one-third, though the fraction varies by aircraft type) remain on main operating bases, while the remainder may be located at civilian airfields, which do not actively support combat sortie production (because few weapon supplies are available there). Thus, full dispersal makes aircraft more survivable at the cost of reducing the combat sortie potential of aircraft (by partially removing them from the weapons required for combat sorties).

Table 9

AIR BASE TYPES

| Air Base Class | Description |
|---|---|
| Military, Bomber (MAIR_bomber) | Military-owned air bases that in peacetime contain either strategic bombers or strategic tankers, or military air bases likely to support bombers in a forward deployment into a theater. |
| Military, C3 (MAIR_c3) | Mili ry-owned air bases that in peacetime are major bases for command, control, and/or communications aircraft. |
| Military, Major (MAIR_major) | Military-owned air bases that in peacetime contain a wing/regiment or so of tactical combat aircraft. |
| Military, Minor (MAIR_minor) | Air bases that in peacetime contain a squadron or so of tactical aircraft, or would receive military aircraft in a major deployment (with appropriate facilities, etc.). |
| Civilian, Major (CAIR_major) | Airfields not counted above with at least one runway of 9000 feet or more length and 150 feet or more width that has a permanent surface. |
| Civilian, Medium (CAIR_medium | Airfields not counted above with at least one runway of 5000 feet or more length and 50 feet or more width that has a permanent surface. Presumed to be the primary dispersal bases for tactical aircraft. |
| Civilian, Minor (CAIR_minor) | Airfields not counted above with at least one runway of 4000 feet or more length and 30 feet or more width that has a permanent surface. |
| Civilian, Small (CAIR_small) | Airfields not counted above with at least one runway of 2000 feet or more length and a permanent surface, or 3000 feet or more length and a nonpermanent surface. |

As noted above, the sortie rates can be further modified by owner and location sortie rate multipliers. These reflect, for example, the ability of a country to generate more sorties with its aircraft because of better training or other factors, or, alternatively, the effect of a poor environment (such as a lack of fuel or maintenance supplies or an attack by chemical weapons--something that is not explicitly modeled at present), which reduces sortie generation within a specific region (for example, "set region FRG sort_mult 0.5").

## COMMAND AND CONTROL OF TACTICAL AIRCRAFT

Tactical aircraft may be assigned to one of four command structures:

- A combat theater (e.g., WTVD)
- A Pact front or NATO air force (e.g., 2 ATAF)
- An independent Air Army (e.g., the Legnica Air Army)
- A naval carrier task group

Aircraft assigned to the first two command structures receive their missions and allocations directly from those command structures. Control of Air Army or carrier aircraft may be temporarily transferred to a theater or a front by issuing a Delegate order, which specifies the percentage of the Air Army or carrier assets by type that are made available to each theater or front (for example, 50 percent of the interdiction aircraft and 20 percent of the fighters may be delegated from a carrier task force to support AFNORTH). Aircraft delegated to a theater receive missions separate from those specified for theater controlled aircraft and have a separate interdiction plan.

## AIR MISSIONS

Within each theater or front, the commander uses the Apportion order to designate the percentage of aircraft that are to perform each of several possible missions. The missions for Blue single-role aircraft are shown in Table 10. In turn, multi-role aircraft are apportioned to any of the interdictor missions or to air defense, with priority given to having the multi-role aircraft most capable of fighter operations fly as fighters and the remaining aircraft most capable of CAS performing the CAS mission. Multi-role aircraft performing air-

Table 10

MISSIONS FOR THEATER SINGLE-ROLE COMBAT AIRCRAFT

| Aircraft class | Mission | Description |
|---|---|---|
| | **Blue** | |
| *Fighter* | | |
| | Air defense | Defense against Red penetrating aircraft |
| | Escort | Protection of Blue penetrators |
| *CAS* | | |
| | CAS | Attacks against FLOT ground forces |
| *Interdictor* | | |
| | Offensive counterair | Attacks against Red air forces |
| | Defense Suppression | Attacks on Red air defenses |
| | Air interdiction | Attacks against all other Red targets |
| | CAS | Attacks against FLOT ground forces |
| | BAI | Attacks against reserve ground forces |
| | Quick reaction alert | Aircraft withheld on nuclear alert |
| *Medium-bomber* | | |
| | Offensive counterair | Attacks against Red air forces |
| | Air interdiction | Attacks against general Red targets |
| | Quick reaction alert | Aircraft withheld on nuclear alert |
| | **Red** | |
| *Fighter* | | |
| | Airfield defense | Defense of Red air bases |
| | Area defense | Defense against Blue penetrating aircraft |
| | Corridor security | Defense of Red penetration corridors |
| | Cover | Protection of Red direct support aircraft |
| | Attack | Fighter sweep against Blue airborne command/control/intelligence aircraft |
| | Escort | Protection of Red penetrators |
| *CAS* | | |
| | Direct support | Attacks against FLOT ground forces |
| *Fighter-bomber* | | |
| | Defense suppression | Attacks against Blue SAMs |
| | Direct support | Attacks against reserve ground forces |
| | Direct support, CAS | Attacks against FLOT ground forces |
| | Airfield interdiction | Attacks against Blue air forces |
| | Air interdiction | Attacks against all other Blue targets |
| | Nuclear reserve | Aircraft withheld on nuclear alert |
| *Medium-bomber* | | |
| | Airfield interdiction | Attacks against Blue air forces |
| | Air interdiction | Attacks against all other Blue targets |
| | Nuclear reserve | Aircraft withheld on nuclear alert |

to-ground missions may defend themselves against opposing aircraft when required.

The Soviet theater combat air missions are also shown in Table 10. Note that there are, in some cases, significant differences between the Soviet and U.S. missions, reflecting our understanding of the operational differences. Red multi-role aircraft are apportioned to either the fighter-bomber missions or to airfield or area defense, with the aircraft relatively more capable as fighters performing the fighter missions. As with Blue, multi-role aircraft may defend themselves when on air-to-ground missions.

When apportioning either Blue or Red sorties to missions in a given theater, CAMPAIGN allows separate Apportion orders to be entered for each Major Agent (the United States and the Soviet Union), for its allies, and for Air Army or carrier aircraft delegated to the theater. This would allow the Soviets to use their allies' aircraft on less critical missions.

Interdiction missions for both Red and Blue are further refined through a targeting plan. Blue first specifies a targeting plan for air interdiction and one for offensive counterair. Red indicates how air interdiction and airfield interdiction will be targeted. Sample Red and Blue plans are shown in Table 11. For example, 60 percent of the CEur air interdiction sorties will be targeted in East Germany (GDR) against a laydown called AI-NucStor.

The laydowns referenced in Table 11 are an aggregation of target types. Table 12 illustrates two typical laydowns. The first indicates that 80 percent of the weapons targeted against this laydown in any given region will go against major military airfields, while 20 percent will go against their dispersal airfields. The second indicates that 90 percent of the sorties will attack nuclear weapon storage sites, while 10 percent will be placed against nuclear weapon storage dispersal sites. There are approximately 100 different target types in CAMPAIGN, and each has four possible types of sites associated with it: (1) a primary site, (2) a dispersal site, (3) and a relocatable site (e.g., for ground forces moving away from any kind of base), and (4) other

Table 11

SAMPLE WTVD AND CEUR TARGETING PLANS

| Theater | Plan | Laydown Name | Target Region | Percentage of Sorties | Load |
|---|---|---|---|---|---|
| CEur | AI | AI-NucStor | GDR | 60 | conv |
| | | AI-LOCs | Poland | 10 | conv |
| | | AI-LOCs | Czech | 10 | conv |
| | | AI-LOCs | GDR | 20 | conv |
| | OCA | OCA-1 | GDR | 60 | conv |
| | | OCA-2 | Poland | 15 | conv |
| | | OCA-1 | Czech | 25 | conv |
| | NonThtr | OCA-1 | GDR | 100 | conv |
| WTVD | AI | AO-NucStor | FRG | 60 | conv |
| | | AO-Ports | Belgium | 10 | conv |
| | | AO-Ports | Netherl | 10 | conv |
| | | AO-LoCs | FRG | 20 | conv |
| | AI-AFLD | AO-Airbase-1 | FRG | 70 | conv |
| | | AO-Airbase-2 | Belgium | 15 | conv |
| | | AO-Airbase-1 | Netherl | 15 | conv |
| | AirArmy | AO-Airbase-1 | FRG | 70 | conv |
| | | AO-Airbase-2 | Netherl | 15 | conv |
| | | AO-Airbase-2 | Denmark | 15 | conv |

Table 12

SAMPLE LAYDOWNS

| Laydown Name | Target Type | Site | Percentage |
|---|---|---|---|
| OCA-3 | MAIR_major | prim | 80 |
| | MAIR_major | disp | 20 |
| AI_NucStor | STOR_nucwpn | prim | 90 |
| | STOR_nucwpn | disp | 10 |

sites (e.g., where weapons are targeted for pin-down or pattern attacks). Weapons expended against dispersal or relocatable sites go against known or suspected sites, which may be a small fraction of the total.

Interdiction, multi-role, and bomber aircraft may also be called upon to carry out special attacks through the use of the Strike order. Strikes take precedence over other aircraft missions. A Strike order identifies a number of sorties of a particular type that are assigned to strike a set of targets in some region, using any of the weapons that can be placed on the given aircraft and for which supplies exist.

Once sorties have been apportioned to missions, it is then necessary to allocate CAS, BAI, and direct support sorties to specific combat axes. This is done using the Allocate order, which simply indicates the percentage of sorties allocated to each axis in a given theater. Other aircraft missions are assumed to occur in the theater as a whole or in specific countries, and not within particular axes (for example, air bases in East Germany may be attacked, but not air bases in axis 5).

## AIR COMMANDER

An "Air Commander" is being developed as a counterpart to the Ground Commander described in Sec. VI. It will produce Apportion and Allocate orders for those users who wish such support. The Apportion logic focuses on the objectives desired (for example, if Red desires to run an Air Operation or an Air Defense Operation) and related issues required to provide necessary guidance (such as target prioritization for use in related Laydown orders). The Allocate logic looks at those axes with greatest need based upon specified criteria and sets the percentages allocated appropriately. Currently, the Allocate logic is operating as planned, and the Apportion logic is in an early stage of development.

## NUCLEAR OPERATIONS

Nuclear operations with theater aircraft are simulated in two ways in CAMPAIGN. First, aircraft associated with a broad strike plan (coordinated with strategic targeting) are executed on specific options using the Execute order. Second, aircraft can be sent on nuclear missions in specific areas using the Strike order.[2] In either cases, the assigned nuclear missions take precedence over conventional missions, with available sorties released to the nuclear missions first (starting with aircraft on nuclear withhold). If any sorties remain after nuclear sorties have been executed, then they will operate according to the Apportion and Allocate orders described above (with the provision that the nuclear withhold percentage is reduced by those aircraft that have been executed on nuclear missions).

## TIMING AIR MISSIONS

Each side may enter three different timing vectors to indicate the relative percentage of its sorties that will fly in each of the six 4-hour theater combat cycles per day. A timing vector is provided for CAS ("cas_timing"), BAI ("bai_timing"), and all other air-to-ground missions ("ai_timing", all three in the "airwar" parameter table). Decisions about timing should reflect: (1) massed air raids, (2) the relative ability of aircraft to fly at night, and (3) the desirability of limiting attrition by flying aircraft at night. For example, if one side or the other would like to perform two large massed raids each day, with a 12-hour day their timing vector might look something like:

[2]Either of these nuclear operations apply equally to VSRBMs (like Lance), SRBMs, MRBMs, IRBMs, GLCMs, and nuclear artillery.

| Time | Period | Percentage AI |
|---|---|---|
| 12a.m. to 4a.m. | night | 4 |
| 4a.m. to 8a.m. | night | 3 |
| 8a.m. to 12p.m. | day | 40 |
| 12p.m. to 4p.m. | day | 15 |
| 4p.m. to 8p.m. | day | 35 |
| 8p.m. to 12a.m. | night | 3 |

Typing "set airwar wtvd ai_timing 4 3 40 15 35 3" achieves this result.

By contrast, air defense sorties are committed over time based upon the opposition threat perceived and do not therefore require a timing vector. The rules for such commitments are based upon a scrambles rate ("para_scram") per opposition penetrator (both air-to-ground and air-to-air aircraft). If this parameter is set too high, raids early in the day will be defended against well, but raids later in the day may face much less opposition; if this parameter is set too low, all raids will be met equally, and some potential sorties will be wasted.

## MISSION SUMMARY AND ENGAGEMENTS

CAMPAIGN takes the Apportion and Strike orders entered and formulates ground attack sorties into an eight element matrix, as shown in Table 13. For example, if there are 1000 Blue interdiction aircraft apportioned 20 percent to BAI, 30 percent to air interdiction, and 50 percent to OCA, and 200 medium bombers apportioned 40 percent to air interdiction and 60 percent to OCA (with no Strike orders and no nuclear missions), then the conventional BAI box would show 200 sorties, the conventional AI box would show 380 sorties, and the OCA box would show 620 sorties, with the other boxes (except CAS missions) showing zero sorties. Each entry also includes an average quality figure for the sorties apportioned to the indicated mission, calculated based upon the quality of the individual aircraft involved.

Table 13

MISSION SUMMARY TABLES

Air-to-Ground sorties

| Weapon type | CAS | BAI | AI | OCA |
|---|---|---|---|---|
| Nuclear | Strikes and Executes | | | |
| Conventional | CAS and multirole aircraft | BAI mission aircraft | Strikes and AI mission | Def Sup, OCA mission |

Blue escort and Red air defense

| | | | | |
|---|---|---|---|---|
| Blue Escorts | None | Escort | | |
| Red Air Defense | None | Area Defense | | Airfield Defense |

Red Air-to-Ground sorties

| Weapon type | CAS | Dir. Supp | AI | AI-Afld |
|---|---|---|---|---|
| Nuclear | Strikes and Executes | | | |
| Conventional | CAS aircraft | Direct support mission | Strikes and AI mission | AI-Afld and Def sup |

Red escort and Blue air defense

| | | | | |
|---|---|---|---|---|
| Red Escorts | None | Cover mission | Escort and corridor security | |
| Blue Air Defense | None | Area Defense | | |

After the air-to-ground sorties are apportioned, the escort and air defense sorties are apportioned. For Blue, escort sorties are apportioned across BAI, Strikes, AI, and OCA in proportion to the number of air-to-ground sorties being flown in each box in Table 13. Thus, in the example above, if 120 Blue escort sorties were to be flown, 20 would go with BAI mission aircraft, 38 with AI, and 62 with OCA. Air defense is similarly apportioned, except that Red airfield defense sorties are only flown against Blue OCA aircraft, as Table 13 indicates (CAMPAIGN currently adjusts airfield and area defense somewhat to respond to the Blue attack).

The results of Tacair engagements are resolved separately for each of the eight entries in the air-to-ground mission summary tables for each side. Note that for both Blue and Red, no escorts or air defense sorties are apportioned to CAS missions, and so there is no air-to-air battle for this class of mission (CAS mission aircraft suffer only ground-to-air attrition).[3] The other six entries in each side's ground-to-air mission tables, and the appropriate allocation of escorts and air defense aircraft, are analyzed separately to determine the results of penetration (over the organic SAMs and the SAM belt), air-to-air combat, and the delivery of air-to-ground munitions. If any individual table entry is zero, it is ignored in this processing.

## AIRCRAFT ATTRITION ON MISSIONS

For the various air-to-ground missions described above, the first step in adjudication is to determine how many aircraft are lost in flying each mission. Losses occur either to SAMS and other surface-to-air threats or in air-to-air engagements. All losses (to both ground-to-air and air-to-air threats) can be reduced by flying at night.

**SAMS and other Surface-to-Air Threats.** All penetrating aircraft must cross both the organic air defenses of the FLOT and a (possible) SAM belt both on entering and exiting enemy territory. In addition,

[3]A proposed methodology enhancement will change this assumption and allow for a forward air battle where CAS mission aircraft can be engaged in air-to-air combat.

aircraft flying deeper than those performing BAI must also face area and terminal SAMs.

The attrition suffered from organic air defense is a function of the basic kill potential of the defenses (flot_kill), the current capability of those defenses to cover the ground forces (density), and the effectiveness of the command control system (effectiveness):

loss_rate = flot_kill * density * effectiveness * strength

Currently, we define effectiveness as being equal to the average cohesiveness of forces in a particular sector. Strength is the strength of the air defenses in the given sector relative to the baseline air defense strength for which flot_kill was calculated. The density calculated depends upon the character of the mission being flown: CAS aircraft are assumed to be flying where the density of air defenses is the highest (where combat is most intense) in each sector, whereas BAI and other penetrating aircraft are assumed to penetrate over areas with average or less defense and to be less exposed to organic air defenses. For example, assume that flot_kill is 3 percent, and effectiveness and strength are 1.0 (early in the war). For CAS aircraft, the density will usually equal 1.0, so the CAS loss rate will be 3 percent in this case to organic air defenses (the only threat faced by CAS in the current version of the model). For penetrating aircraft, the density factor will tend to be 0.3 to 0.5, reflecting the more general spread of forces across each combat sector; thus penetrating aircraft will lose 0.9 to 1.5 percent to organic air defenses. Note that with penetrators, the model also assumes an intelligence function that allows the attacker to observe organic losses and adjust his penetration sectors over time to reduce those losses.

The attrition suffered from a SAM belt (e.g., a Hawk or SA-4 belt) is a function of the capability of the belt, the extent to which penetration corridors have been punched in the belt, the extent to which the penetrators know where the holes in the belt are, the presence of defense suppression aircraft to keep the defenses occupied, and the ammunition supply of the belt. This model is currently being adjusted to correspond with a similar model of strategic aircraft penetration against a SAM belt so that an integrated methodology is used.

The attrition suffered from area and terminal SAMs is a function of the capability of these SAMs, the extent to which they have been suppressed, and the presence of defense suppression aircraft to keep the defenses occupied.

**Air-to-Air Engagements.** For the various air-to-air combat analyses described above, the capability of the air-defense aircraft and escorts is summed based on the ability of the aircraft to perform their specific role. Essentially, the resulting sum indicates how many F-15 equivalents will be engaged on either side. This figure will be degraded when any aircraft no longer has available its required high-tech air-to-air munitions (the degradation is aircraft-type specific and should reflect the fact that even when the best air-to-air munitions are exhausted, older air-to-air missiles and possibly some trickle of the higher technology missiles would still be available). The percentage of attrition is then calculated as:

$$\text{escort\_loss} = \text{air\_pk} * \left[ \frac{\text{equivalent\_defenders}}{\text{equivalent\_escorts}} \right]^{.8}$$

$$\text{defender\_loss} = \text{air\_pk} * \left[ \frac{\text{equivalent\_escorts}}{\text{equivalent\_defenders}} \right]^{.8}$$

For example, if the air-defense fields 200 F-15 equivalents to the escorts 100, and the air_pk is 3 percent, then the escort losses would be 5.2 percent (5.2 aircraft) and the air-defense losses would be 1.7 percent (3.4 aircraft).

Losses to the aircraft being escorted is determined in two steps. First, we estimate the number of air-defense aircraft that penetrate the escort screen (eff_def):

$$\text{eff\_def} = \text{equivalent\_defenders} * .5^{\frac{\text{equivalent\_escorts}}{\text{equivalent\_defenders}}}$$

Thus, if the equivalent escorts and equivalent defenders are equal, half of the defenders will be able to attack the penetrators; if the equivalent escorts are twice as many as the equivalent defenders, then only one-fourth of the defenders will be able to attack the penetrators.

In the second stage, the percentage of penetrators lost is calculated as:

$$\text{pen\_loss} = \text{pen\_pk} * \left[ \frac{\text{eff\_def}}{\text{penetrators}} \right]^{.7}$$

Where "penetrators" is the number of penetrators, and pen_pk is the loss rate expected when the number of eff_def is equal to the number of penetrators (that is, if one F-15 equivalent sortie was launched in defense and penetrated fighter cover for each penetrator).[4] For example, if the bomber_pk is nominally 30 percent, and 2000 bombers and interdictors penetrate with 1000 F-15 equivalent escorts against 500 F-15 equivalent defenders (yielding eff_def of 125), the bomber loss rate would be about 4.5 percent (or 90 aircraft).

Both air_pk and pen_pk are reduced by flying sorties at night.

**The Effects of Losses and Aborts.** Losses are apportioned to ingress and egress to determine the appropriate number of air-to-ground aircraft able to attack their assigned targets. The ingress losses are multiplied by an abort rate when over a specified threshold to reflect the fact that the number of aircraft that abort their missions will be a function of the heaviness of the defense (reflected by the losses the defense is able to impose).

[4]The pen_loss is limited to a specific maximum value, currently 80 percent.

## GROUND ATTACKS

The procedures for assessing the damage caused by CAS and BAI sorties have been described in the previous section. In addition, the current version of the attrition model does not damage organic air-defense systems based on ground-force engagements; rather, organic air-defense systems are only damaged by CAS, BAI, and helicopter strikes, and at the same rate of loss charged to maneuver forces. Similarly, attrition to the SAM belt, area SAMs, and terminal SAMs is caused by defense suppression and interdiction mission aircraft targeted on defenses and depends upon the ability of these aircraft to find and destroy SAM sites.

Attacks on other types of targets are adjudicated based upon the size and type (conventional versus nuclear) of weapons load that each aircraft can carry and the accuracy with which those weapons can be delivered. While we include any of the variety of high-tech munitions in this area (such as runway denial munitions or cluster bombs) as possible weapon loads, the mechanisms for adjudicating the damage they would cause are not currently available.

Besides the CAS and BAI missions discussed previously in the text, the current version of CAMPAIGN shows the most effect on interdiction against airfields and against lines of communication. With attacks on airfields, CAMPAIGN simulates both damage to aircraft (accounting for the number sheltered versus those unsheltered) and damage to the airfield itself, the latter resulting in a degradation in the sortie generation capacity of the airfield. Strikes against lines of communication slow the movement of units through the interdicted areas, but currently do not slow the flow of supplies.

# IX. COMBAT SUPPORT

Besides the repair of equipment and facilities, strategic lift, and barrier construction issues handled above, we have just begun to model the entire combat support area in three parts.

**Ground Supplies.** Supplies for ground forces are handled only approximately. Each unit is assigned a given number of "days of supply," a simple aggregation of all types of ammunition. A theater reserve pool of supplies is also created for each nationality, measured in terms of "division-days of supply," and located in various storage areas. Units consume one day of supplies when attacking, and some relative number when defending, when not in combat or when in high intensity combat. A unit will request resupply from its nationality's theater stocks when its own supply levels become low; priority on resupply is given to main thrust axes. As a unit's supplies draw close to zero, it will reduce its level of combat (lower its EED score) and may be required to withdraw from combat to be resupplied. When supplies are exhausted in the theater, the forces are unable to continue combat. The model also follows the interoperability issue, noting the percentage of a nation's supply requirements that can be met by its allies' supplies if it exhausts its own supplies.

**Air Supplies.** A much more detailed approach is followed for aircraft munitions, identifying types of munitions such as Sparrows or Mavericks and indicating for each aircraft type how many of each type of munition are required for a given kind of mission. National stockpiles of weapons are provided for each region of CAMPAIGN.

For air-to-air and air-to-ground missions, a nominal high-tech and low-tech load may be specified for each type of aircraft, consistent with the aircraft performance factors given for each. Once the high-tech supplies are exhausted, the effectiveness of each sortie is reduced to the low-tech level.[1] Attack helicopter munitions are carried only as generic high-tech or low-tech supplies (without referring to type), and

[1]That is, once the main supplies of high-tech munitions are

lead to a fractional degradation once the high-tech supplies are exhausted. Resupply is handled by analyst-scripted "deliveries" from outside the theater.

**War Reserve Stocks.** Each country has an inventory of in-theater war reserve stocks (ground-force weapons) by weapon type, including both quantity and quality information. As attrition occurs, these stocks are issued to the units that are not engaged in combat at a maximum percentage absorption per day, restoring at least some of the initial unit capabilities. These stocks may be replenished from the repair cycle or by analyst-scripted "deliveries" from outside the theater.

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exhausted, only a trickle of high-tech may be expected thereafter, augmented by other, lower effectiveness munitions. Thus, the loss in effectiveness assumes some continued, but sharply reduced, flow of high-tech weapons.